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Front cover: Aerial image of raised container beds at a seed production area. Photo: Shannon Shumski. Read more in the article by Paul Gibson-Roy (p. 7-9, this issue).

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This issue

Regular features

From the editor

HEIDI ZIMMER

Welcome to another bumper issue of Australasian Plant Conservation! This issue is packed with papers from the Australasian Seed Science Conference (held back in 2021). We begin with an article from Tina Bell and colleagues about native grasses, and their use as a food source. Bell *et al.* discuss everything from native grass seed germination to baking properties. Paul Gibson-Roy then introduces us to the efforts of Kalbar Operations in ecological restoration in East Gippsland, Victoria, including development of a seed production area. Next, we head west, where Jenny Guerin *et al.* describe the challenges of working with orchid seeds, and their success with *Caladenia gladiolata* in South Australia. This is followed by an article by Lorena Ruiz Talona and Andrew Gardiner, in which they describe the potential benefits of seed coating (used to modify seed physical properties or deliver ingredients to the seed), including easier handling and better germination.

Next we have three articles which take a historical perspective of seed science, each demonstrating how actions in the past have been the basis for development of the approaches we use today. Amelia Martyn Yenson and colleagues present a history of seed collection, storage and use at the Royal Botanic Gardens and Domain Trust (RBGDT). Andrew Crawford then reflects on the achievements of the Western Australian Seed Centre (WASC) over the past 30 years. Both the WASC and RBGDT have made significant contributions to securing the future of many threatened Australian plant species. This is followed by an article by Christopher Sauer which tells the story of Native Seeds/SEARCH, a not-for-profit organisation based in Arizona, USA, which has a focus on conservation of seeds from arid-adapted plants from Greater Southwestern USA, with the aim of improving both human nutrition and biodiversity.

The final two conference articles are focused on data. Nathaniel Kingsley and colleagues describe their program to image seeds stored in the Lyon Arboretum Seed Lab at the University of Hawai'i, and database these images for use by researchers who do not have direct access to the collection. Last, Anne Fuchs *et al.* detail the approach and methods used in databasing at the Australian National Botanic Gardens, including the National Seed Bank.

We round out the issue with our regular features. For the Australian Seed Bank Partnership (ASBP) news, we have an extract from the ASBP annual report 2021–2022, sharing highlights (and brilliant images) of the partnership's work across Australia. We then have an ANPC project report, Tony Auld and others discuss progress on the San Diego Zoo Wildlife Alliance (SDZWA) project to assess the impacts of the 2019–2020 fires on priority plant species. We end with a tribute, book review and ANPC news.

Native grasses as a traditional and emerging source of food

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We pay our respects to the people of the Gamilaraay and Yuwaalaraay country in north-west NSW where much of this research was done. We also pay our respects to the Gadigal people of the Eora Nation on whose traditional lands the researchers and students who were involved in the research are based. We acknowledge colleagues and students that have been part of this journey.

Introduction

Australian native grasses have been used by Aboriginal communities as a food source for thousands of years (Balme *et al.* 2001). Grain from native grasses contains fibre required for gut health, essential minerals, and relatively large amounts of protein in some species (Keitel 2020, *unpublished*). Recently, there has been considerable interest in the commercial development of flour and processed products derived from native grass grain, and the associated benefits for land and people. A multidisciplinary research team, composed of the authors and other researchers based at The University of Sydney, have been part of this renewed activity.

Traditional agricultural grain production (*e.g.*, wheat, barley) requires large inputs in the form of fertilisers, pesticides, and water and is characterised by low biodiversity. In turn, perennial native grasslands can cope with low nutrient soils and stressful growing conditions such as seasonal and prolonged drought (Garden *et al.* 2001). Importantly, they are associated with high biodiversity (NSW Office of Environment and Heritage, 2012) and can regenerate naturally (Potter *et al.* 1999; Gibson-Roy 2018). Native grasslands are in serious decline because of widespread clearing for agriculture (Kirkpatrick *et al.* 1995). However, due to their adaptation to the Australian landscape and climate, they have the potential to be grown in marginal areas of farms and degraded landscapes currently not used for traditional grain or food production (NSW Office of Environment and Heritage 2012). Promoting the use of native perennial grass species can help improve native grassland diversity and health. For this to happen, landholders need to understand possible benefits, including native grains as a food commodity, to encourage investment into and management of native grasslands.

Paddock-to-plate

In 2020, we investigated the value chain, from 'paddock-to-plate', of a theoretical production system for native grains. The research highlighted the current and potential future bottlenecks for developing a modern take on traditionally important food production systems (Pattison *et al.* 2020). What set our research apart was that a range of different aspects of the whole paddock-to-plate system were considered including growing, harvesting, and threshing of grass, nutrition, food development, economics, and marketing. The team focussed strongly on developing research questions in collaboration with Aboriginal stakeholders, and the study identified tangible benefits for both Indigenous and non-Indigenous people. The research gaps in the use of native grains in modern food production systems and the importance of involving Aboriginal stakeholders from the beginning have been highlighted in a recent review (Drake *et al.* 2021).

Our study involved research that was wide ranging. At the start of the value chain, we investigated growing and harvesting grain from native grasses, including cleaning, and milling of grains (Figure 1A). Unlike modern crops such as millet and wheat, native grass seed is small, difficult to separate from florets and the seed does not all ripen at the same time – across a paddock or even within single flowerheads.

In the middle of the value chain, we created food using native grains and investigated the properties of flour including nutrient content, appearance, and baking qualities (Figure 1B and C). Grass flour does not contain gluten which adds challenges to commercial baking but adds a lucrative element in marketing. In addition, grain sourced from different populations of the same species may have different properties. For example, bran and white flour from two populations of *Panicum decompositum* (Native Millet) had marked differences in colour compared to each other and to wheat (Figure 1D) (Widjojo 2017, *unpublished*). With this in mind, we investigated the importance of seed provenance of native Australian grasses in germination requirements.

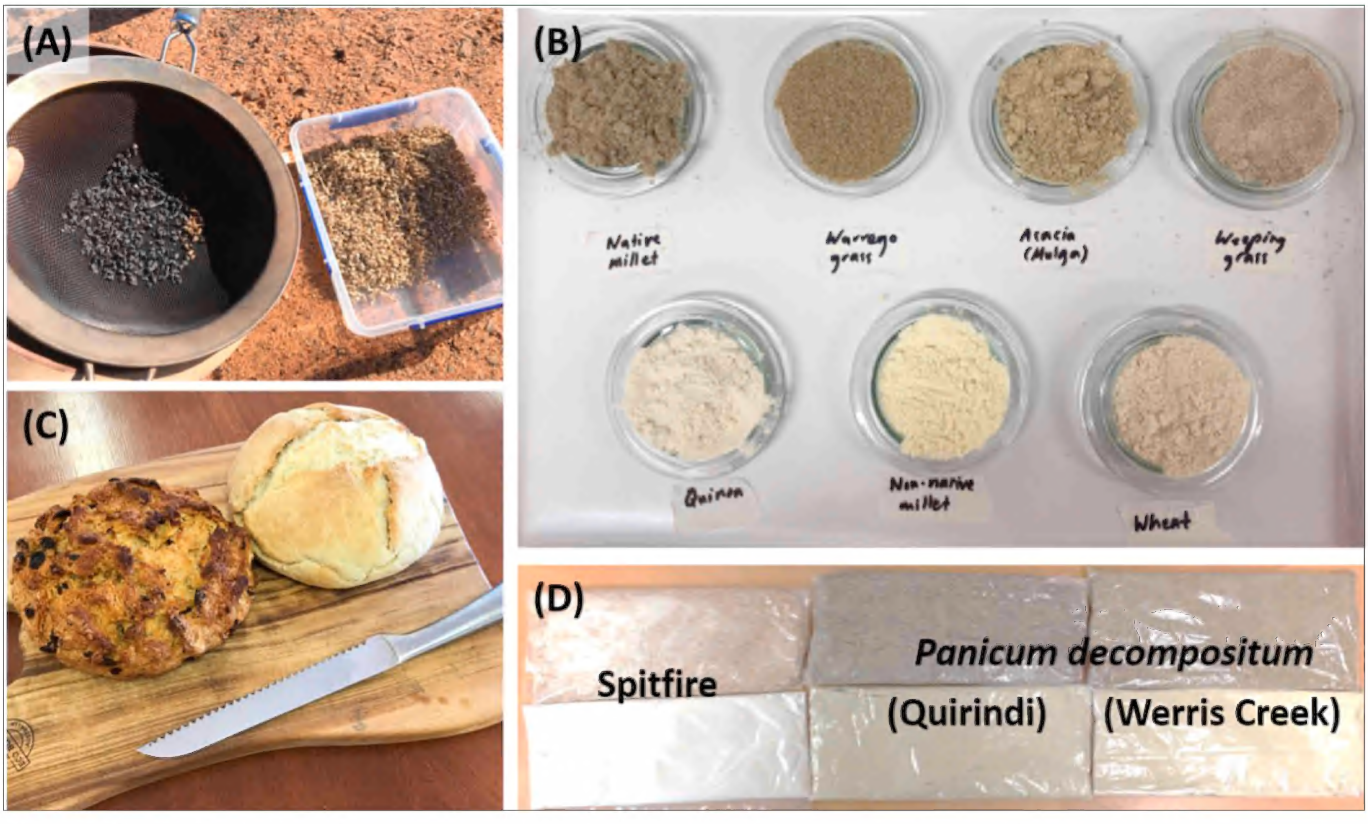

Figure 1. (A) Charring of harvested florets of *Astrebla lappacea* (*ganalay* or Mitchell Grass) prior to threshing, using modern tools but the same principle as historic treatment of seed prior to threshing to loosen and reduce the husk, (B) differences in colour and consistency of flour from native grains (top row: *Panicum decompositum* (*guli* or Native Millet), *Paspalidium distans* (Warrego Grass), *Acacia* sp. (Mulga), *Microlaena stipoides* (Weeping Grass)) and commercial grains (bottom row: quinoa, non-native millet, wheat), (C) baked sourdough products using 5% (F5) flour from *A. lappacea*, (D) wholewheat flour (with bran, top row) and white flour (without bran, bottom row) of wheat (Spitfire) and *P. decompositum* harvested from two populations showing variation in colour. Photos: Sam Padgett (A,B) and Angela Pattison (C,D)

At the end of the value chain, colleagues from economics investigated the commercial potential for growing native grass in an agricultural setting (Phillips 2020) while our business colleagues reviewed the state of the commercial market that food products containing native grains would enter (Laurie 2020).

Germination of grass seed

Data on seed properties of native Australian grasses, including their germination requirements, is comprehensive for some species (*e.g.*, *Themeda triandra* (Kangaroo Grass); Snyman *et al.* 2013), but not for others. In general, little is known about the biology and management of native grasses and other grassland species (Cole and Johnston, 2006). This is not unexpected as the success of different species of grass varies with local climate and the fire regime of the area (Morgan and Lunt 1999; Clarke and French 2005). Fire-related cues (*i.e.*, smoke, heat) can enhance germination of some native Australian grasses (Read and Bellairs 1999; Clarke and French 2005), and post-fire conditions can promote growth (Moore *et al.* 2019), but for some species, germination success is poor because of low seed viability or mechanisms promoting seed dormancy (Farley *et al.* 2013; Pedrini *et al.* 2019).

We have measured the germination response of a broad range of grass species, including those with edible grain, to fire-related cues (Pagett 2018, *unpublished*). Treatments included exposure to smoke (10 min), heat (2 min at 60 °C), and ash leachate (10 g L^{-1} ash leachate in water agar) which were compared to controls (no treatment; Figure 2A and B). Seed from 17 species was germinated on water agar at room temperature (approximately 20 °C) under ambient light conditions. As far as possible, the seed was collected by the same commercial supplier, was the same age and stored in the same conditions.

With no treatment (*i.e.*, control), *Dichanthium sericeum* (Queensland Blue Grass) had the greatest germination (84%) which was even more successful when treated with smoke (97%). Seven species had greater than 25% seed germination with no treatment, but most species exhibited low germination success regardless of treatment. Germination of seed of *Cymbopogon refractus* was significantly greater with addition of ash leachate (48%) compared to no treatment (25%). Seed of *Paspalidium distans* (Spreading Panic Grass) did not germinate at a high rate but was significantly better with exposure to smoke (18%) compared to no treatment (9%). In contrast, germination of seed of

Digitaria brownii (Cotton Panic Grass) was significantly reduced by all treatments compared to the control (42% germination) and most strongly with exposure to smoke (27% germination).

For two species, *Themeda triandra* (Kangaroo Grass) and *Cymbopogon obtectus* (Silky Head), we obtained seed from two wild populations each. Using the same treatments – smoke, ash, and heat –germination success was low overall (20% or less) but, for both species, heat and ash leachate treatments had lower germination for one population compared to the other (3-5% lower than the control). In another experimental configuration, seed of *Themeda triandra* (Kangaroo Grass) harvested by different methods – hand harvested from two wild populations or machine harvested from two sown paddocks (see Figure 2C) – also showed differences in germination success. Importantly, there was no evidence of machine-harvesting reducing germination due to damage to seed; variation in germination was more likely due to provenance (Pietz 2016, *unpublished*). Both pieces of information are important to know if Indigenous communities want to harvest seed to use in regeneration, but also for creating paddocks producing seed to harvest for food.

We used four species to investigate the effect of different types of ash leachate on seed germination in the context of preparing paddocks for creating areas for harvest of native grass seed (Figure 2D). Burning removes weeds and old growth and potentially adds nutrients for plant growth. Ash from three burning scenarios was collected and incorporated into water agar. Again, we found different responses for different species but the overall picture was that ash leachate did not inhibit germination and, for some species, promoted germination.

Co-researching with community

Above all else, the most important lesson we learnt from the paddock-to-plate project was that co-research with local community as partners is key. Our research is aligned with Indigenous seed, food and land sovereignty and underpinned with upholding Indigenous rights to Indigenous Cultural Intellectual Property (ICIP) (see Janke 2021).

Figure 2. (A) Germination of native grass on water agar (left) and water agar made with ash leachate (right), (B) colour variation of ash leachates – ash is mixed in water and allowed to settle, filtered then used to make agar plates for seed germination, (C) car-towed harvester (Rosevale Reaper Grass Seed Vacuum Harvester) modified to include brushes to assist collection of target seed species from mixed stands of native grasses, (D) cool burning of trial stands of Native Millet and Mitchell Grass in 2022 to determine, among other things, which harvesting conditions produce the most edible seed in the next season. Photos: Tina Bell (A,D) and Angela Pattison (B,C)

Working with Indigenous and non-Indigenous partners to build a community of practice for sharing information and knowledge about growing native grasses will be essential going forwards. Our collective and fundamental aim is to support the generation of an Indigenous owned and led native grains industry for the environmental, social, cultural, and economic benefit of all.

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Striving for TEC restoration – securing native seed supply

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Background

Ecological communities are naturally occurring and interacting groupings of native plants and animals in a unique habitat. Their structure, composition and distribution are determined by environmental factors including soil type, landscape position, climate, water availability *etc.* (DCCEW 2022). They become *threatened ecological communities* (TECs) when changes to their natural composition and function are affected or altered to the degree that they are exposed to extinction risk (*i.e.*, through clearance, inappropriate fire regimes, invasive species, climate change, water diversion, pollution, urban development).

Gippsland Red Gum Grassy Woodland and Associated Native Grassland is a critically endangered TEC in south-eastern Victoria, reduced in extent from ~120,000 ha to between 900 to 5,600 ha - a 95% to 99% decline (Lunt 1994, 1995, 1997; EPBC 2008). It is dominated at canopy level by Gippsland Red Gum (*Eucalyptus tereticornis* subsp. *mediana*) while a wide range of grass and herb species dominate underneath. Its primary threats are clearance, fragmentation, inappropriate management, weed invasion, pest animals, and rural tree dieback (EPBC 2008). EPBC listing has resulted in conservation actions that are the primary tool for its preservation with several programs established under the Australian Landscape Trust, Gippsland Plain Conservation Management Network and various Landcare groups (EPBC 2008).

The Fingerboards project

The *Fingerboards* is a proposed mineral sands project located in East Gippsland Victoria (Figure 1). Owned by Kalbar Operations, it seeks to mine zircon, titanium and rare-earth minerals using progressive strip-mining across a ~1,200 ha project footprint over a 20-year period. Project assessments (EHP 2020) showed 90% of the land had been modified with ~60% improved pastures, ~30% blue-gum and pine plantation forestry and 10% supporting native vegetation (concentrated around roadsides and dissecting gullies). Mining will result in clearance of 1,400 large trees, 1.74 ha of EPBC-listed Red Gum grassy woodland and 9.91 ha of State-listed Forest Redgum grassy woodland, all requiring biodiversity offsets.

Figure 1. Proposed project location.

Restoration goals and challenges

Kalbar's environmental objectives aim to minimise negative and maximise positive effects consistent with or exceeding industry practice (and be applicable to state and federal legislation, policies, standards, and guidelines). Requirements under Section 78 of the Victorian Mineral Resources (Sustainable Development) Act 1990 suggest mine licensees focus on *'the desirability or otherwise of returning agricultural land to a state that is as close as is reasonably possible to its state before the mining licence, prospecting licence or extractive industry work authority was granted'*. However, this project has ambitious rehabilitation goals to restore native vegetation across the whole project footprint, including 200 ha of Red Gum grassy woodland TEC into an area previously occupied by plantation forestry. However, TEC restoration by its nature is difficult because native seed (a critical component for restoration, is inevitably in short supply due to community rarity. A linked issue is the under-resourced nature of the restoration sector, which is constrained in capacity from decades of poor regulatory support (Gibson-Roy *et al.* 2021 a & b).

Addressing these challenges

Kalbar is addressing these challenges by committing to develop cultivated Seed Production Areas (SPAs) which are known to be effective in generating seed from wide ranges of species (Gibson-Roy 2018, Pedrini *et al.* 2020, Gibson-Roy *et al.* 2021, Zinnen *et al.* 2021).

The project devised a 2-phase plan, with phase-1 focussed on developing an initial 1 ha 'stepping stone' SPA and, from this, generating seed resources required to establish a second larger 8 ha phase-2SPA following mine approvals, from which the bulk of seed for restoration would be generated. A secondary aim for a smaller SPA is to (i) trial cropping systems and set-up methods to inform the design and operation of the phase-2 SPA and (ii) to train a local workforce in plant cultivation and maintenance, seed collection and processing.

Over 3 years from 2019 to 2021, plans and actions were developed to achieve these goals. A small project team was assembled and focussed on locating remnants, undertaking seed collections, and assisting in SPA construction and operation. Collection licences were granted by regulators and harvests to establish founder SPA crops were undertaken each season (over the whole ripening period) for 3 years within the mapped range of the TEC, providing seed from ~150 herbaceous and sub-shrub species.

By good fortune, a disused wholesale plant nursery was identified, leased and modified from a plant- into a seed-growing SPA over 3 years (Figure 2). Three crop bed systems were developed; (i) weed-mat beds, (ii) vertical trellis beds and (iii) raised container beds (Figure 3 A-F). Bed footprints for each species matched projected seed requirements. Approaches trialled included topsoil removal prior to laying weed mat (to reduce weed seed loads), integration of organic composts (to improve water holding capacity and soil structure), sub-surface and surface dripper irrigation (to reduce water use and improve plant water access), overhead irrigation (to irrigate seedlings and pulse irrigate crops), crop separation structures/componentry (to exclude seed of other species from beds), altered planting densities (to improve seed yields) and varied planting/seeding approaches (to increase installation efficiency), and differing collection methods/technologies (to improve harvest yield and efficiency).

Figure 2. Aerial image of the phase-1 SPA in November 2021. Photo: Shannon Shumski

Nursery infrastructure was also established that included work areas, propagation and growing houses, seed processing areas, and seed storage facilities (*i.e.*, cool room) (Figure 4 A-C). In tandem with SPA actions, staff undertook on-ground assessments to inform restoration planning included baseline monitoring of the project site for soil textural, structural, nutritional, microbial and seed-bank characteristics. Community engagement during this period aimed to inform the local community, stakeholders and agencies about the works being undertaken.

What worked, and what did not

While conservation is critical, experience has shown that in highly cleared arable landscapes, ecological restoration is one of few options available for increasing TEC range and quality, however, seed supply issues must be adequately addressed for this to be feasible (Gibson-Roy 2018, Gibson-Roy 2022). The Fingerboards project shows that in a relatively short period it was possible to develop strategies and undertake the types of action required to begin building the scale of SPA capacity required to generate seed resources for large-scale TEC restoration. The phase-1 SPA represented infrastructure enabling the project to grow over 150 rare species and to produce quantities of seed that would otherwise be unavailable from remnants. The development and operation of the SPA also increased significantly local capacity and experience.

In December 2021, when plans were well advanced to begin building the 8-ha phase-2 SPA, the project's EES assessment was delivered by the planning minister and the project based on the assessment requires some modification (as outlined by the Independent Advisory Committee report). Kalbar has maintained the smaller SPA (and actions focussed on the larger SPA have been paused). What sets this project apart from typical mine programs is a commitment to undertake a scale and type of restoration that goes magnitudes beyond what is required by mining regulators. Perhaps even more significant, is that these goals were financially supported for several years so that SPA capacity could be developed well in advance and in readiness for restoration action. This is a commitment few mining companies have demonstrated.

In Victoria and Australia more generally, the restoration sector is poorly developed and/or supported, meaning little large-scale high diversity ecological restoration is undertaken, and effectively no TEC at-scale restoration. When the Fingerboards project is approved, it will provide a template for restoring TECs at-scale, including the critical aspect of building seed supply through SPA development. In doing so it will also raise the bar, not only for the mining, but for the broader restoration sector.

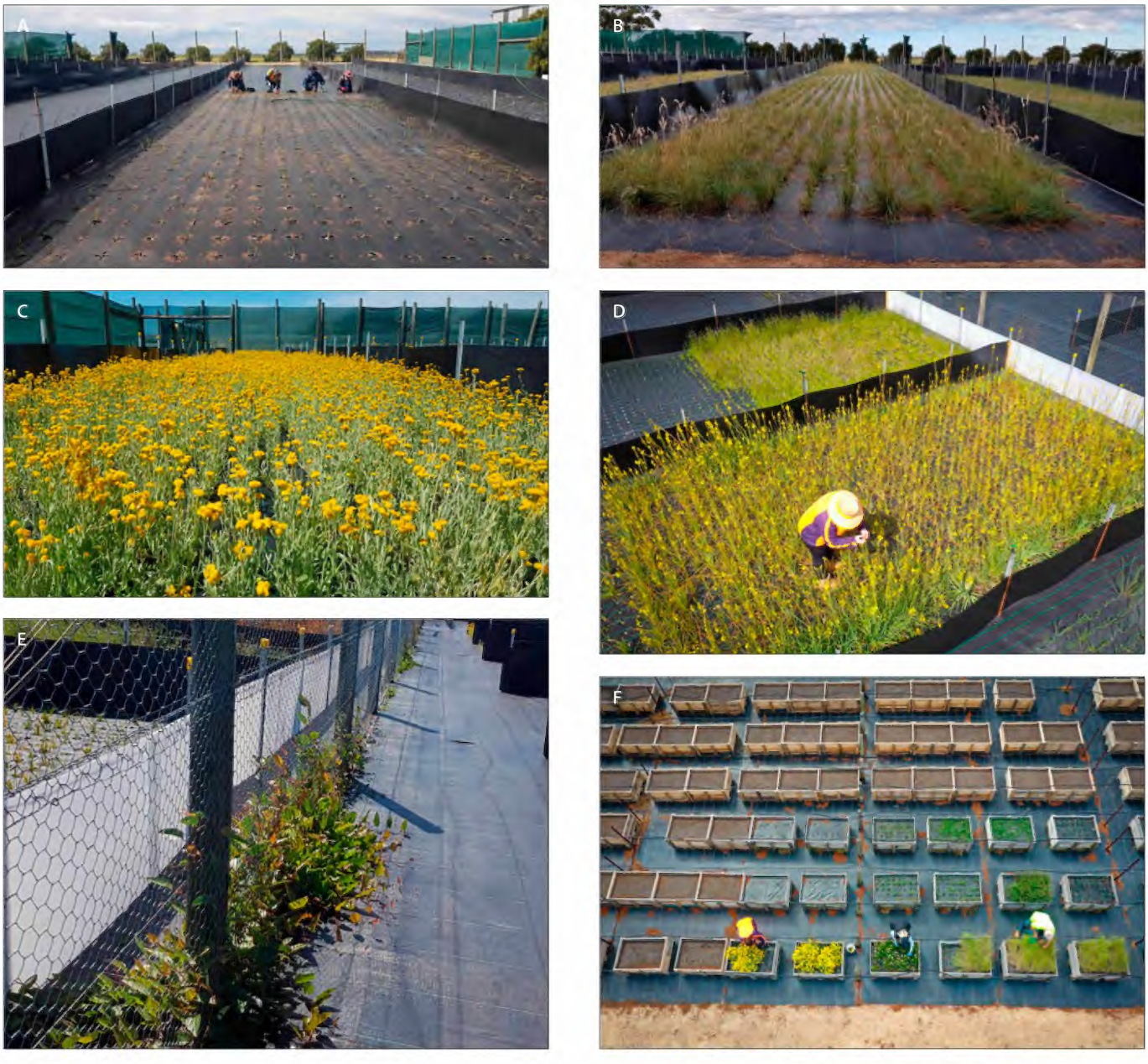

Figure 3. (A) Weed mat grass bed planting. (B) Weed mat grass bed established. (C) Weed mat daisy bed. (D) Weed mat lily bed. (E) Trellis bed. (F) Raised container beds. Photos: Paul-Gibson Roy (A-C,E) and Shannon Shumski (D,F)

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Figure 4. Nursery infrastructure. (A) Propagation house. (B) Growing house. (C) Seed cool room. Photos: Paul Gibson-Roy

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Conservation of threatened orchids in the Mount Lofty Ranges

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The South Australian Seed Conservation Centre (SASCC) began conserving the State's threatened flora in 2003. Currently 85% of threatened flora is conserved *ex situ* in the seed bank. In the early years, seed collection targets covered a broad range of plant families. Orchidaceae was not an initial focus, due to limited funding combined with the complexities of seed storage and specialised propagation methods. *Ex situ* conservation of orchids requires storage at ultra-low temperatures and the SASCC lacked technical capacity for isolating, utilising and storing the symbiotic fungi required for seed germination and plant propagation. Consequently, during the first 10 years of the SASCC less than 20 orchid seed collections were banked.

In flora conservation there is no doubt that orchids are a high priority. Around 16% of the State's threatened flora belong to Orchidaceae and approximately 50% of SA orchid species are listed as threatened. The continuing decline of orchid populations was noted by a number of our partners and expert volunteers over the years and highlighted the need to conserve seeds *ex situ* and to develop symbiotic *in vitro* propagation for recovery projects.

A trial project was suggested in 2015 to investigate sponsorship to support collections and symbiotic *in vitro* propagation for three endangered orchid species in SA. The three species were the Blue-top Sun-orchid (*Thelymitra cyanapicata*; Forestry SA), White-beauty Spider-orchid (*Caladenia argocalla*; private donor), and the Bayonet Spider-orchid (*Caladenia gladiolata*; Native Orchid Society of South Australia). This project partnered with Dr Noushka Reiter at the Royal Botanic Gardens Victoria and enabled the technical capacity and resources to undertake symbiotic *in vitro* propagation of orchids to be developed in SA.

A case study example that highlights the success achieved by working with partners to develop the technical capacity to recover threatened orchid species is the Critically Endangered Bayonet Spider-orchid. This orchid is only known from two widely separated localities in South Australia: the Alligator Gorge region in the Southern Flinders Ranges and the Scott Creek area in the Mount Lofty Ranges. The latter population has only a few flowering plants and survey efforts had not located any other plants in recent years. There were no recent seed collections from this population and, after attempts to cross-pollinate flowers failed to achieve seed pods, the outlook for this population was becoming critical.

However, a seed collection from the late 1990s was held in the seed centre and a plan was initiated to collaborate with Dr Noushka Reiter to restore plants to the Mount Lofty Ranges. In 2015, symbiotic mycorrhizae were isolated in Dr Reiter's lab at Cranbourne. The isolates proved effective for seed germination and plants were propagated in the nursery and transported back to Adelaide. Flowering nursery plants were cross-pollinated using pollen from the original population for seed production. These plants were more vigorous compared to the wild population and produced large amounts of seed that could be used for long term storage as well as propagation. After successful cross-pollination in 2018 a seed collection was also achieved from the wild population.

In partnership with the Back from the Brink project (Hills and Fleurieu Landscape Board) the outlook for *C. gladiolata* has continued to improve. A new site with 15 flowering plants was located during a dedicated search effort after a wildfire in the Scott Creek area in the summer of 2021. Seeds were collected and used for propagation of hundreds of plants. Two translocations have already been undertaken in the area with more scheduled over the next few years. Conservation efforts through these partnerships have greatly improved the chances of long term survival of the Bayonet Spider-orchid in the Mount Lofty Ranges.

Encouraged by the success of these initial projects, the SASCC has continued to acquire equipment and experiment with propagating a range of orchid genera. There are now 725 orchid collections held by the SASCC and up to 15 species are propagated each year for recovery projects. There have been multiple translocations for over 20 species over the last three years. Historic seed collections have provided valuable genetic diversity for recent projects. For example, the 2020 bushfires destroyed a population of *Pterostylis cucullata* subsp. *sylvicola* (Leafy Greenhood) in the Adelaide Hills that was then re-planted using seeds banked from the same population in the previous year. Orchid-related activities, including population survey, seed collection, propagation and translocation, have comprised approximately half of the SASCC program in recent years. These actions reflect the direction of the program overall, as the focus has widened from banking seed collections to include on-ground recovery of these species in partnership with Landscape Boards, ecologists and Friends of Parks groups.

***Caladenia gladiolata* flowers at Scott Creek. Photo: Jerry Smith**

Seed coating: effects on seed germination, handling and costs associated

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Australian native seed is a limited and expensive resource, and difficult to source sustainably in the bulk amounts required to meet the demands for national and local restoration goals (Hancock *et al.* 2020). Direct seeding is often recommended as an alternative to seedling planting. Seed-coating could contribute to improve results when direct seeding.

Seed coating consists of applying constituents to the surface of the seed and it is mainly used to modify its physical properties and/or to deliver ingredients (Pedrini *et al.* 2017).

Why coat seed?

The physical characteristics of seeds of many Australian species make them difficult to use in mechanised seeding. Seeds can be small, light, fluffy, spikey, uneven, sticky, clumpy, *etc.* (Fig.1). Such seeds are often excluded from direct seeding projects. Seed coating is likely to improve seed use as it:

- Produces uniform elements, easier to handle.
- Allows more control of the seed amount, sowing rates, and seed spreading than uncoated seed thus reducing seed waste.
- Can be used by any spreading machine minimising delivery failures.
- Adds protection to seed.

Coating seed

We coated two types of seed to determine whether seed coating is a feasible technique, in terms of ease of use, costs, and effects in germination.

Techniques

We film-coated seeds of Queensland blue grass (*Dichanthium sericeum*), to modify their shape and size and improve handling and spreading with conventional direct seeding equipment.

Film coating consisted of adding layers of coat up to (1) duplicate or (2) triplicate the original seed weight.

With seed of *Eucalyptus coolabah,* we produced pellets to overcome the inconveniences of small-sized seed, including seed waste and difficulties to spread evenly and accurately in direct seeding.

Pelleting consisted of (1) coating seeds with chaff in small clumps; (2) seed attached to a carrier by the coating (Fig. 2). In both coatings we targeted an average

Figure 1. Fluffy grass seed (left) and germinants of tiny melaleuca seed (right). Photos: Lorena Ruiz-Talonia

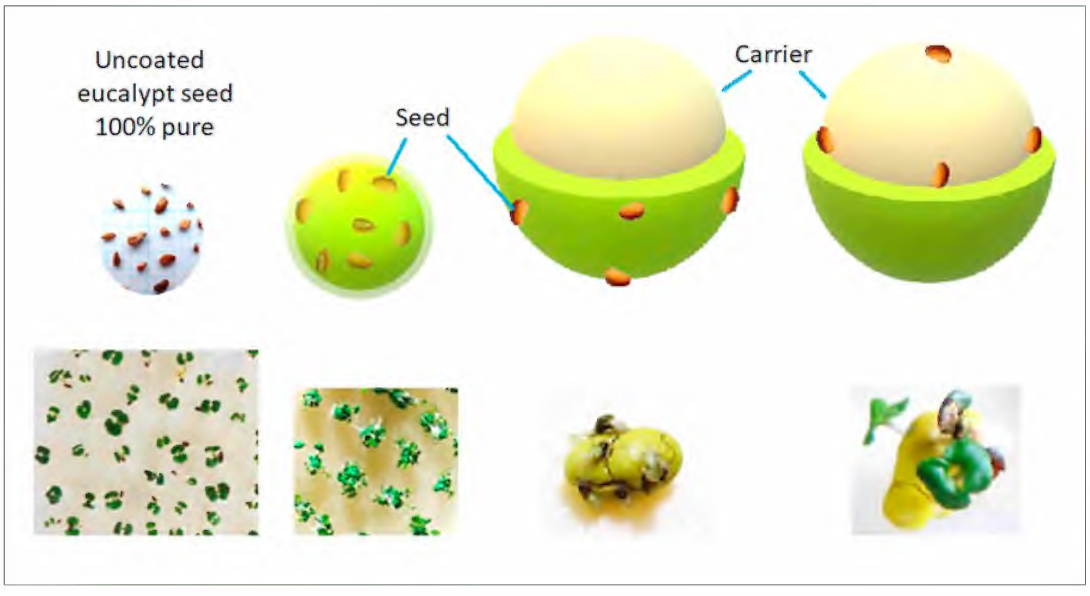

Figure 2. Representation of the techniques used for coating eucalyptus seed and examples of germinants below each. Photo: Lorena Ruiz-Talonia

of seven viable seeds per pellet to ensure at least one germinant. Initially, rice was used as a carrier only, as a cheap alternative to test the mechanics and logistics of the technique. Note that a different non-biological carrier is essential for actual effectiveness of this technique in the field.

Germination tests

We compared the germination of coated and uncoated seed of grass and eucalypt: (1) in Petri dishes under controlled conditions in growth cabinets, and (2) in clay soil obtained from the seed collection site in a nursery, either sown at the surface or buried 6 mm.

We also assessed seed handling and delivery in an agricultural spreader and a drone. Finally, we estimated the cost-benefit of seed coating.

Findings

In the growth cabinets

Germination of coated and uncoated seed was alike for both eucalypt and grass seed. Consequently, we obtained 7±4 germinants from each eucalypt pellet. Germination of eucalypt seed from pellets that were too embedded within the coat was 2–3 days slower and some later germinants occurred along with fungus contamination.

In the nursery

All uncoated and coated grass and eucalypt seed germinated equally well when sown on the surface which was consistent with germination in the cabinets.

When buried, germination of coated seeds of eucalypts was three times better than that of uncoated seed (6 per pellet or 86%, vs 2 germinants out of 7 or 28%).

Germination of buried coated grass seed was also higher than uncoated seed (87% and 63%).

Handling

Coating grass seed flattened the fine seed hairs, evened seed shape and size, and facilitated further removal of non-seed material. A thicker coat resulted in cleaner seed and easier management and delivery.

Coating eucalypt seed delivered pellets of a manageable size with established number of seed contained in each. Pellets allowed even and visible spread, preventing the uneven dispersal that often occurs when small uncoated seeds bulked with particles of different sizes and weights settle out within the hopper

Coated seed allowed a better and more consistent flow than uncoated seed in both an agricultural spreader and sowing drone which improved the precision of delivery of both types of seed (Fig. 3).

Figure 3. Grass seed coated until weigh was duplicated (left) and the same seed passing through a drone box (right). Photos: Andrew Gardiner

Costs

Table 1 Costs of seed alone vs coated with either of the two tested techniques in both species (price as per Biobank Seed 2022). Estimates are per Kg of product. Germinants refer only to estimates of the buried seed, as differences were only detected in those, and are also the closest representative of real sowing conditions.

	Qld Bluegrass seed			Eucalyptus sp.		
	AUD	Viable seeds	Germinants	AUD	Viable seeds	Germinants
Uncoated	$300	54,000	21,000	$1,000	2,850,000	412,000
Coated technique 1	$210	28,000	15,200	$400	620,000	535,000
Coated technique 2	$167	12,000	9,600	$120	125,000	106,000

Conclusions

1. For many native species, like most eucalypts, planting seedlings is generally a safer option than direct seeding for revegetation. Still, when no alternative is available, seed coating is likely to enhance direct seeding, principally when using mechanical spreaders.
2. Our results and estimated costs suggest that 1kg of coated seed is overall more convenient than 1 kg of uncoated seed. The more expensive the uncoated seed, the greater the savings by coating, and the least seed waste of small seeds.
3. Seed coating can reduce seed cost and waste, ease seed delivery, and potentially increase the chances of success in direct seeding, that is, when combined with appropriate site preparation and seedling care.
4. By improving seed handling alone, seed coating allows the inclusion of a wider range of species in direct seeding mixes when using mechanical spreaders.
5. Obtaining low germination rates from sowing large amounts of native seed is unsustainable (*i.e.,* millions of eucalypt seed in 1 kg)
6. If the results from the nursery can extrapolate to the field, seed coating might be advantageous especially for small-seeded species by extending the microenvironmental conditions suitable for germination. This hypothesis was formulated after observing that wetting coats hold moisture and would germinate even when buried.
7. The coated and uncoated seeds from these experiments (except seed in a carrier), were already used in direct seeding projects as requested by customers, and although better results of coated seeds were perceived, no follow up evaluation was undertaken.

Future targets:

- Explore different types and sizes of carriers for small seed, and suitable seed content per pellet. Clay balls (2 mm) have proved the most successful carrier so far.
- Incorporate active ingredients to the coat to further protect the seed or to enhance emergence and establishment (*i.e.*, insecticide).
- Test our hypotheses that pellet size or coat thickness is correlated to germination timing and increased microenvironment range for germination.
- Research coated seeds in the field.

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History of seed collection, storage and use at the Royal Botanic Gardens and Domain Trust

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The knowledge and technology available to support seedbanking has developed considerably in the last 35 years, with common goals provided by the Global Strategy for Plant Conservation and funding through the Millennium Seed Bank Project and other initiatives. Changes at The Australian PlantBank – formerly the NSW SeedBank and now a component of the Australian Institute of Botanical Science – are one example of the parallel changes in purpose and mission to collect wild species.

Our target species have changed over time: initially curating collections for the development of the Australian Botanic Garden, Mount Annan; expanding to include conservation of threatened species; and more recently, addressing the challenges of conserving rainforest seeds and orchids using a variety of *ex situ* methods including cryopreservation. Current projects are supported by a range of partners, including the NSW Government's Saving our Species program, the Australian Seed Bank Partnership and The Ian Potter Foundation.

With an increasing quantity and diversity of seed collections in storage, comes the challenge of curating existing collections so they are available in coming decades. Management action taken now depends on collection quality and quantity, which has been influenced by the seed drying and storage conditions and associated technology available at the time of collection (Merritt *et al.* 2021).

Figure 1 describes advances in seed drying, storage conditions, supporting technology and the changing mission, targets and outputs of the *ex situ* conservation program, which is a key focus of the Australian Institute of Botanical Science.

Merritt, D.J., Whitehouse, K.J., Hoyle, G.L., Crawford, A.D., Wood, J.A., Satyanti, A., Norton, S., Errington, G., Martyn Yenson, A.J. (2021) Chapter 5 Seed banking: orthodox seeds. In: Martyn Yenson, A.J., Offord, C.A., Meagher, P.F., Auld, T.D., Bush, D., Coates, D.J., Commander, L.E., Guja, L.K., Norton, S.L., Makinson, R.O., Stanley, R., Walsh, N., Wrigley, D. and Broadhurst, L. (Eds.) '*Plant Germplasm Conservation in Australia: strategies and guidelines for developing, managing and utilising ex situ collections. Third edition*.' Australian Network for Plant Conservation, Canberra. Available at: https://www.anpc.asn.au/plant-germplasm/

History of seed collection, storage and use
at the Royal Botanic Gardens and Domain Trust

Image: Richard Weinstein

- **We are storing living collections of an increasing diversity of NSW plant species**. Our ex situ (offsite) collections provide an insurance policy against extinction of native plants in the wild.
- **We are refining our understanding of the best way to store different species:** seed, tissue culture, cryopreservation or plants in the nursery and garden, or a combination of these methods.
- **We are active partners in conservation with Australian and global networks** responding to threats such as bushfires, plant diseases and climate change.

NSW Seedbank redevelopment

Millennium Seed Bank partnership begins

	<1987	1987-1999	1999	2003-2009
Seed drying	· Room conditions	· Heated airing cabinet or air conditioned room	· Seed drying room: 15% RH, 15°C	· Seed drying room: 15% RH, 15°C
Storage conditions	· Room temperature and humidity 	· Commercial drinks fridge (5°C) 	· -18°C walk-in freezer for long term storage · 4°C walk-in coolroom for short term storage	· -18°C walk-in freezer for long term storage · 4°C walk-in coolroom for short term storage
Technology	· Glass jars 	· Vacuum sealed plastic laminated foil envelopes · Tissue culture		· Zig-zag aspirator to clean seeds (2004) · Expanded germination testing capacity (2007)
Mission/ targets/ outputs	· Located at the Royal Botanic Garden Sydney site · Used for botanic garden development and international seed exchange 	· Moved to the Australian Botanic Garden Mount Annan to provide living collections for the new botanic garden · Horticultural development and tissue culture of Waratahs and Flannel Flowers · 1994: Wollemi Pine discovered	· NSW Treasury funding for major upgrade of NSW Seedbank to support conservation of NSW native species, including threatened species. 	· Millennium Seed Bank partnership begins, which supports an expanded statewide seed collecting program and increased capacity for seed testing and research. Increased collaboration with Australian conservation seedbanks · Dryland/orthodox species collected eg. Acacia, Eucalypt


Wollemi Pine


Zig-zag aspirator 2004

AUSTRALIAN INSTITUTE OF BOTANICAL SCIENCE

The Royal Botanic Gardens & Domain Trust

Figure 1. History of seed collection, storage and use at the Royal Botanic Gardens and Domain Trust, with reference to advances in seed drying, storage conditions and technology, and the changing mission, targets and outputs of the *ex situ* conservation program.

Australian PlantBank opened

	2009-2012	2013	2016 – Present
Seed drying	• Seed drying: 15% RH, 15°C	• Seed drying: 15% RH, 15°C	• Expanded capacity and new drying technology, 15% RH, 15°C (2020)
Storage conditions	• 4°C walk-in coolroom (fridge) • -18°C walk-in freezer • Tissue culture	• 4°C walk-in coolroom (fridge) • -20°C walk-in freezer (two: one in use, one for expansion) • Tissue culture	• 4°C walk-in coolroom (fridge) • -20°C walk-in freezer (two: one in use, one for expansion) • Tissue culture • Cryopreservation of sub-samples of incoming seed collections from 2019
Technology	• X-ray machine (2011), Digital microscope (2012)	• Cryostorage facilities 2013	• Differential Scanning Calorimeter 2018 • Bar coding of seed packets for database recognition • Increased use of DNA technology
Mission/ targets/ outputs	• Cryostorage research (ultra low temperature -196°C) • Alpine seed research • Orchid seed and fungi cryopreserved • Initial screening of rainforest seeds for desiccation tolerance funded by Allianz and private benefactors 2010 • On-site restoration of local species following African Olive control	• Rainforest Seed Conservation Project funded by the Arcadia Fund and others • Cryostorage research • Seed collection projects with Australian Seed Bank Partnership (1000 Species and Global Trees projects) • Plant disease Myrtle Rust prompts urgent ex situ collection development within plant family Myrtaceae • Persoonia research	• Conservation focus: Saving our Species program initiated by NSW state government to address threats to plant extinction • Increased focus on translocation of threatened species • Rainforest Seed Conservation Project continues, funded by The Ian Potter Foundation (2019) • PlantBank team win BGCI International Global Seed Conservation Challenge in 2017

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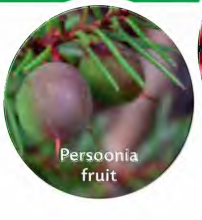
The Royal Botanic Gardens & Domain Trust



Thirty years of seed conservation in Western Australia

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The Southwest of Western Australia is recognised as one of 36 global biodiversity hotspots; that is a region with over 1,500 endemic plants species which has lost over 70% of its primary vegetation. Because of land clearing, and a range of other threats, Western Australia has a high number of plant species considered to be threatened and at risk of extinction and is home to almost a third of Australia's threatened plant species, most of which occur in the Southwest region of the state.

In the early 1990's it was recognised that the soil-borne pathogen *Phytophthora cinnamomi* was a major threat to many plant species in Western Australia and in late 1992 a conservation seed bank, the Threatened Flora Seed Centre (TFSC), was established; the first of its kind in Australia. The specific purpose of the centre was to capture the genetic diversity of Western Australian plant species threatened by *P. cinnamomi*. Over time, the focus of the collection has expanded from just species at risk from *P. cinnamomi,* to encompass all Western Australia's conservation-significant plant species. These comprise threatened species as well as priority species; species which may be threatened but are currently data deficient or are rare but not threatened and require regular monitoring. The TFSC was originally located in transportable buildings at the old Western Australian Herbarium. In 2010 the centre moved to a new, purpose-built facility, and was then renamed the Western Australian Seed Centre, Kensington (WASC-K). The centre forms part of the Keiran McNamara Conservation Science Centre, along with the Western Australian Herbarium and other conservation facilities such as the Sid James Conservation Genetics Laboratory.

When the TFSC was established, there were over 1,700 species of conservation significance in Western Australia, of which 43 were presumed to be extinct. Since then, the number almost doubled, with over 3,500 conservation significant species now recognised (Table 1). To put it in perspective, there are now more species of conservation significance in WA than there are native plant species in Britain.

So, over the thirty years of its operation, how successful has the WASC-K been at conserving the state's conservation significant plant species? The simplest measure would be to consider the proportion of these species that have been collected and stored.

For the state's Threatened plant species, 2,792 collections, representing 347 species have been collected (81% of threatened species). Of the 3,254 priority species, 1,262 collections have been made from 747 species (23%).

Table 1. A comparison of the number of conservation significant plant species in Western Australia between 1992 and 2022 (Smith & Jones 2018).

Conservation status	Year	
	1992	2022
Threatened	270	429
Priority	1,415	3,254
Presumed extinct	43	15

The seed centre laboratory, then (1990's) and now. Photos: Michael James, Andrew Crawford

Whilst the proportion of threatened species collected may appear high, most of the collections are small and fall below the 3,000 and 10,000 seed considered ideal for a conservation seed collection (Cochrane *et al.* 2021). Of the thousands of threatened species seed collections held in the centre, nearly a quarter consist of fewer than 100 seed, and 80% are smaller than 3,000 seed; just 10% of threatened species collections are larger than 10000 seed. In isolation the size of most of these collections would limit their utility for conservation.

Repeat collections are therefore made with the aim of ensuring sufficient seed is stored. For threatened species the number of collections made per species ranges from a single collection up to 71 collections. The average number of collections made per species is seven. When the total seed held for threatened species is considered, over two thirds are represented by more than 3,000 seed, with close to half having more than 10,000 seed.

Whilst the quantities of seed stored for most threatened species appears adequate, summarising to the species (taxon) level fails to reflect the main purpose of the WASC-K, that is to store a genetically representative sample of species in sufficient quantity to facilitate species recovery. The collection strategy of the WASC-K aims to sample the genetic diversity of a species both within and between populations (see Cochrane *et al.* 2021). Where distinct conservation units of a species are known (Coates 2000) or suspected, the aim is to ensure each is conserved.

An example of the importance of representing conservation units is illustrated through the WASC-K's work on conserving *Stylidium coroniforme*. When this species was first collected in the early 1990's, the species was known from two distinct, and disjunct, clusters of populations (conservation units) occurring over 100 km apart. When these collections were made, an effort was made to sample populations in both conservation units. The value of taking this approach has been validated in recent years as a better understanding of the species has developed. Taxonomic and genetic studies have shown that what was thought to be a single species comprising two conservation units, is in fact two distinct species (*S. amabile* and *S. coroniforme*). New populations of *S. coroniforme* have been found in the intervening years, disjunct from previously known populations. These new populations were found to be a distinct subspecies within *S. coroniforme* (*S. coroniforme* subsp. *amblyphyllum*) (Wege & Coates 2007). Seed collections have now been made from this new taxon as well as additional collections of the original species and populations.

***Grevillea maccutcheonii*, one of the many Critically Endangered species for which seed has been stored and used in translocations. Photos: Andrew Crawford**

Seed of *Daviesia cunderdin*, one of Western Australia's most threatened plant species. Over a period of twenty years, seed of this species has been collected and banked at the Western Australian Seed Centre, Kensington and used to establish a translocated population of the species. Photo: Andrew Crawford

Conservation seed banks are oft referred to as being safety nets against extinction. The collections of the WASC-K have proven this. The centre currently holds over 50 collections from 20 species collected from populations where there are now no known living plants.

For seed collections to be of use circumventing species extinction, sufficient viable seed is needed for use when required. This means the seed needs to be stored under conditions aimed at prolonging the longevity of the seed. The WASC-K has, since its establishment, utilised accepted long-term seed bank conditions to store its collections. A recent check of the viability of 44 collections stored for over 25 years (representing 5 families, 9 genera and 22 species) found no significant decline in viability for 41 of these collections. Since the late 90's, seed collections held in the WASC-K have been actively used for species recovery, through their use in translocation. To date, translocations have been conducted for over fifty species using seed from the centre.

Over the past thirty years the work of the WASC-K has done much to conserve Western Australia's Threatened plant species. Unfortunately, more is still to be done. The number of threatened species continues to grow, meaning the seed of more species needs to be collected, and where collections have already been made, further collections are required to ensure enough seed is available for recovery efforts such as translocation, and to ensure the diversity of the species has been adequately conserved.

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Themes of a seed bank: Native Seed/SEARCH

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There are numerous motivations for starting a seed bank. Preserving biodiversity while addressing rapid globalisation of industrial agriculture is a common priority for many (Curry 2019; Harlan 1975). Detailed research into the origins of a particular seed bank reveals the way overarching concerns translate into specific organisational themes. Native Seed/SEARCH (NS/S), founded in Tucson Arizona in 1983, helped focus public attention on preserving local seeds in the Sonoran Desert of the southwestern United States (Schmidt 2015).

Some of the founders was university researchers studying arid lands. Their concern with preserving biodiversity, and they were focused on impacts of the Green Revolution program to significantly increase wheat production. Their original research station was located in Mexico near the southern end of the Sonoran Desert, where the Green Revolution was taking place (Laveaga 2021). Regional challenges and opportunities intersected with interests and concerns and brought a particular flavour to NS/S' seed-saving activities.

History

The mid-1970s at Tucson's University of Arizona was a flourishing time for federally funded research at the Office of Arid Land Studies, which received generous grants for research scientists to collaborate across a range of academic departments and outside traditional university structures (Hutchinson 2005). A particular cohort including ecologists, geologists, archaeologists, and anthropologists met for regular *potlatch* or *potluck* (informal group meals with home cooking) dinners and collaborated on articles, fieldwork, and long-term projects (The Seedhead News 2019). Some of the research focused on native plants in the desert, drawing upon historical Indigenous agriculture and, using both linguistic studies and participant observation, modern Indigenous agricultural techniques of the local O'odham Indigenous people (Nabhan 1983). Working with community organisations, they put a public face to research and promoted native plants as a healthy resource for the environment and human nutritional challenges.

As noted by one of the Native Seed/SEARCH founders, Gary Nabhan, before starting the seed saving organisation some of that cohort worked for an apocalyptic-orientated charitable organisation, Meals for Millions (MFM) (Native Seed/SEARCH 2021). Begun in 1946, during threats of post war global starvation, MFM's charismatic founder wanted to solve world hunger through free distribution of cans of a soybean-based super food that provided the equivalent of a "full steak dinner for only 3 cents" (Shurtleff and Aoyagi 2011). The MFM mission changed over the years, and in the early 1980s Nabhan and others were distributing seeds in a MFM partnership with a United States Department of Agriculture (USDA) food aid program. This long-running federally funded program distributes agricultural commodities to low-income families, including iconic government cheese and canned meat products. In Tucson, this included distributing hybrid broccoli seeds to local O'odham farmers.

Instead of these water hungry modern seeds, O'odham farmers requested traditional crops better suited for the local arid environment, including tepary beans, and a distinctive corn with a seven-week growing season adapted to brief summer rains (Native Seed/SEARCH 2021). From previous research, the cohort of researchers

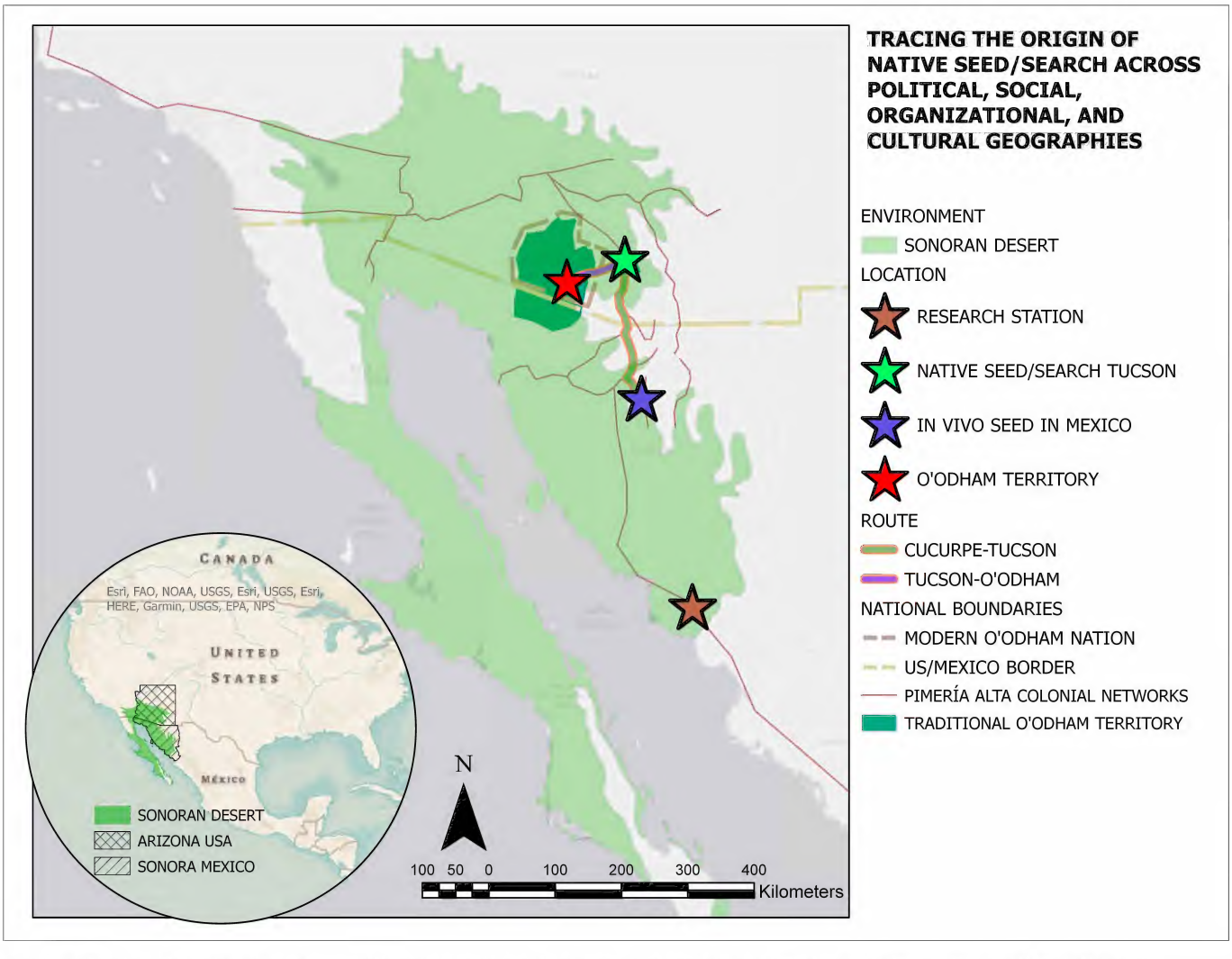

Figure 1. Tracing the origin of native seed/search across political, social, organisational, and cultural geographies. Map: C.P. Sauer

from the University of Arizona knew of such seeds in a Mexican community a couple of hours south, along the edges of the Sonoran Desert (Sheridan and Nabhan 1978). Unfortunately, USDA regulations only allowed distribution of United States sourced seeds. It was in response to this limitation, that Native Seed/SEARCH was formed.

This story illuminates a path through a complicated overlapping set of political, social, organisational and cultural geographies:

- The Mexican *in vivo* seed source, and NS/S' office in Tucson, are both within an historic political and cultural region known as *Pimería Alta* (Indigenous highlands).
- Traditional O'odham territory originally spanned both sides of the increasingly fortified USA/Mexico border.
- Modern highways trace Indigenous pathways followed in the 1500s by Jesuit missionaries who created a network of religious-agricultural settlements using Spanish crops adopted to arid land, including irrigation techniques from Arabic manuscripts (Beekman *et al.* 1999).
- Such crops, adopted by Indigenous and colonial farmers, are in NS/S' collection of heirloom seeds, along with native plants (Nabhan 2018).

Native Seed/SEARCH themes

These geographies illuminate a number of themes to NS/S' organisational practices. They focus on saving seeds together with Indigenous knowledge of agriculture practices. *In situ* preservation happens on NS/S' grow out farm and also through community seed distribution that prioritises reduced cost seeds for Indigenous farmers. In addition to seeds, research into a deep history of traditional agriculture created an appreciation for food from arid lands. Over the years, and in stark contrast to cans of soybean superfood or government cheese, NS/S created a tradition of fundraising events featuring a borderlands gastronomy from native and heirloom seeds (Alvarez and Nabhan 2011; Felger *et al.* 1980; The Seedhead News 1990).

Conclusion

NS/S transformed challenges and limitations into opportunities and resources. Responding to their unique region shaped organisational priorities. In addition to saving seeds, Native Seed/SEARCH addressed other layers of food system challenges, of which loss of biodiversity from industrial agriculture, is but one symptom.

Acknowledgements

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Suc'seed'ing at microscopy: Imaging and digitising the seeds of Hawai'i

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Introduction

Seed banks are critical resources for *ex-situ* conservation and biological research. They are one of the most prevalent and practical approaches to conserving resources used for habitat restoration and the conservation of wild species. Seed banks have also been considered increasingly important in preserving plant biodiversity, serving as repositories of genetic diversity (Gairola *et al*. 2013). Their importance has become increasingly significant for species in delicate, tropical ecosystems such as Hawai'i; where over half of its native flora is at risk of extirpation or extinction due to specific pollinator loss, habitat degradation, invasive species, climate change, and other anthropogenic impacts (Chau *et al*. 2019). Seed collections can also serve as a reference collection for phenotypic analysis and identification, including efforts to generate botanical inventories, track the movement of invasive species, determine the diets of birds and mammals, and identify the remains of plants used by humans or leftover from population declines (Miller *et al*. 2018).

Despite seed collection's utility for research, limitations in terms of accessibility do exist. Travel restrictions, such as time and funding, might impede researchers from accessing seed collections for in-person visits. Further, many seed collections across seed banks and herbaria are not digitised (*i.e*., imaged or databased) or are photographed insufficiently for identification (Miller *et al*. 2019). Technological advances, such as Z-stacking software that can bring into focus an entire specimen with an increased depth of field, have successfully been applied to quantify morphological traits like size and shape (Colmer J. *et al*. 2020). Additionally, these detailed, high-resolution images can be used in accurately identifying species and made available online to researchers worldwide.

Background

The Harold L. Lyon Arboretum is a part of the University of Hawai'i and a public botanical garden. Lyon Arboretum's research and focus on conservation biology has led to the development of the Hawaiian Rare Plant Programme (HRPP), which consists of 3 facilities; a Micropropagation Lab, a Rare Plant Greenhouse, and a Seed Conservation Lab. The Seed Lab was founded in 1995 and is the repository for seed collections within the Hawaiian archipelago. In 2020, a curation project was started to image all 141 genera across 63 families currently held in the Lyon Arboretum Seed Lab in the hopes that it will be a valuable reference to researchers for identification and source for seed morphological data. In addition, we sought to: update the names in the collection to the current taxonomy, photograph the seeds at different focal planes and combine them to increase the depth of field, upload the images onto a newly developed website, SeedsOfHawaii.org, and promote the usefulness of the collection for identification and morphological research.

Nomenclatural updates and collection organisation

The Lyon Arboretum Seed Conservation Lab houses its 29 million seed collection in full-size freezers for orthodox seeds and refrigerators for freeze-sensitive seeds. To guarantee the taxonomy of our collection was updated to the currently accepted nomenclature, we used the Smithsonian's *Flora of the Hawaiian Islands* to standardise and update our list of scientific plant names. The metadata associated with new additions to the collection will be maintained in an Excel spreadsheet and backed up on Lyon's servers, intending to add this data to a relational database in the future.

To increase the utility of the digitised reference collection, we wanted to allow additional images and data to be uploaded to the site as our collection continues to diversify and grow. Having multiple accessions of the same taxon will better denote differences in sizes and shapes that might be present across natural populations. Additionally, to preserve the morphological integrity of the seeds (Nesbitt *et al*. 2003), we elected to image fresher specimens from more recent collections. Consequently, it will serve as a better reference tool for collectors, researchers, and field botanists. Once the inventory sheet was generated, and specimens from each taxon were chosen, the seeds were pulled from storage alphabetically by genus. The seeds are housed in hermetically sealed aluminium foil packets with archival quality label tape denoting species name, accession number, and storage code that indicates frozen or refrigerated (Figure 1a and b).

Figure 1. (a) Various species are organised alphabetically in the freezer at -18°C in labelled containers containing the foil packets. (b) *Dubautia arborea* in an aluminium foil packet that is hermetically sealed and stored in a freezer. Photo: Jaclyn Harvey

Seed photography

To improve the visibility of the Lyon Arboretum Seed Lab and to make its resources available to researchers worldwide, we photographed seeds that best represented each taxon from our entire collection. To observe the seeds in detail, an Olympus SZ-61 Stereo Zoom Microscope with a magnification range of 6.7x - 45x with 100-120/220-240V~ 0.15/0.1A 50/60Hz was utilised (Figure 2a). In addition, an LW Scientific MiniVID Microscope Digital Camera with a fixed microscope adaptor was used for photographing the seeds (Figure 2b). The camera has a mounting size of 23.2-30 mm (C-Mount, ocular tube) and fits a size 3 USB, DC 5V 900mA, with a sensor size of 5.1MP ½.5" APTINA CMOS. The camera is plugged into a laptop through USB and replaces the right ocular lens of the microscope (Figure 2c).

The programme Toupview, a camera control software that allows the adjustment of each image through white balance, exposure, and colour adjustment, was used to capture images of the seeds. First, a range of photos, about 3-6 per specimen, were taken to capture different focal points of the seed. Next, Adobe Photoshop combined these images on the Z-plane, creating one Z-stacked image with greater depth of field and bringing the whole seed into focus. Additionally, a scale bar computed by the software was included in the photos. Finally, Adobe Lightroom was utilised to "clean up" the images. Through the manipulation of contrast, exposure, saturation, highlights, white balance, texture, clarity, and the removal of any chromatic aberration, Lightroom creates high-quality, detailed images of each species.

The morphological variety of the seeds was captured in three images for each specimen, including a "close-up" image of an individual seed; typically, a white background was used to get detailed pictures of the seed edges

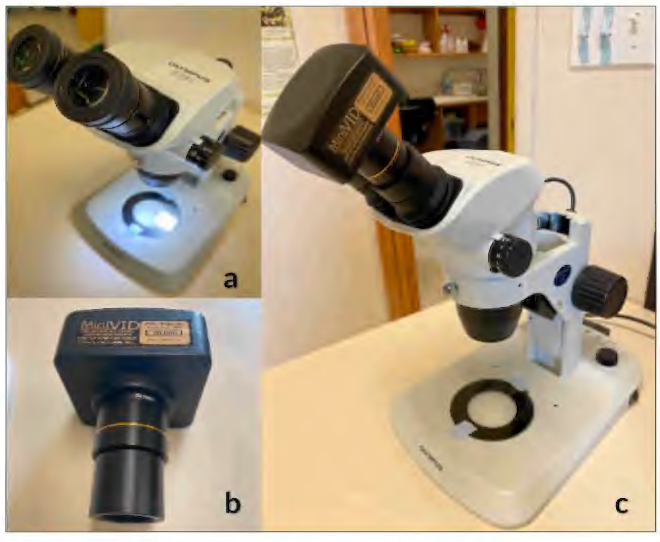

Figure 2. The equipment used in the imaging process. (a) The Olympus SZ-61 Stereo Zoom Microscope enhances the fine detail of the individual species. (b) The MiniVID Microscope Digital Camera with microscope adaptor captured the images of the seeds. (c) The complete setup with the MiniVID mounted within the right ocular lens of the Olympus increases the resolution and allows for digital viewing. Photo: Jaclyn Harvey

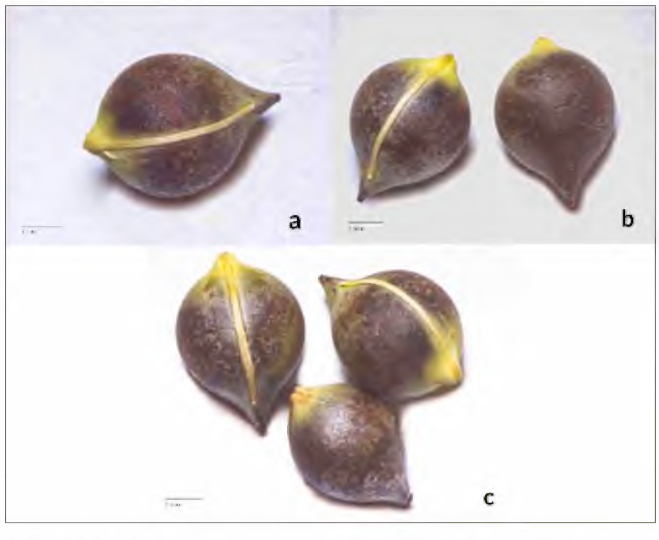

Figure 3. Examples of *Wikstromeia villosa* seed photographs. (a) Close-up, (b) dorsal/ventral or proximal/distal, and (c) cluster arrangement. Photo: Jaclyn Harvey

(Figure 3a). A black or purple velvet background was occasionally used if images on the white background caused distortions of the image. Another image displays the seeds from two sides, either "dorsal/ventral" or "proximal/distal" (Figure 3b). The third "cluster" image highlights the colour, size, or texture variations among multiple seeds of the same species (Figure 3c). The final images are exported from Lightroom as JPEG and TIF files.

Uploading images to *Seeds of Hawai'i*

The Lyon Arboretum website is a datahub for information regarding plant conservation and gardens affiliated with the University of Hawaii at Mānoa. We are currently in the process of uploading all the images of the taxa onto the *Seeds of Hawai'i* website, an extension of the Lyon Arboretum site. In doing so, we will make our collection available to off-site researchers and digitally preserve the morphological characteristics of the specimens. The Seed Lab collection images will be located under the 'Research and Conservation' tab on the Lyon Arboretum home screen (manoa.hawaii.edu), in a subtab titled 'Seeds of Hawai'i' (seedsofhawaii.org). The user interface will be organised alphabetically by family, then genus, with a search bar allowing users to search by family, genus, Hawaiian name, island, or federal listing. The individual species page will have all three images of the seed, a table with associated morphological data (*e.g.*, size and shape), and a Hawai'i map highlighting the distribution of that species across the archipelago. We aim to continue promoting our collection's digital use as a reference for the most extensive morphological database of Hawaiian seeds.

Conclusion

There is a strong connection between seed morphology and storage behaviour within a seed bank, with the majority of seed banks having tiny seeds. Seeds of species that are larger, frequently long or flat, and often have hairs or awns are, more often, underrepresented in seed banks due to their short-lived or recalcitrant nature (Thompson 1987). However, some species have orthodox storage behaviour (*i.e.*, storable at -18°C) and are greater in size than the average seeds held in the Lyon Arboretum Seed Lab. These genera include *Mucuna, Mezoneuron, Canavalia, Sicyos,* and *Zanthoxylum.* We could not use our microscopy techniques to image the species in these genera due to size limitations under the dissecting scope. Instead, macro-photography with a Nikon-D850 DSLR camera and overhead stand will be used to capture images of these species. These images will be uploaded to the database after the microscopy images are all finalised on the *Seeds of Hawai'i* site.

Seed collections are instrumental as a reference collection for identification. Unfortunately, many researchers might not be able to access physical collections due to travel costs. These limitations are especially the case in Hawai'i, one of the most remote archipelagos on Earth. Given these restraints, seed banks are challenged with creating broader access to their collection. Therefore, having visual representations, such as images, of seeds in a digital database can significantly enhance the research value of the collection by broadening its overall access. Photos are easy to share with distant researchers and provide data on the seed's general morphology (colour, size, shape). With technological advances, like Z-stacking capabilities, images can capture the three-dimensional nature and encompass the entire seed in focus. Consequently, seed banks that digitise their collections through modern imagery can expand their utility and use for reference farther than physical collections. The process of imaging the Lyon Arboretum Seed Lab collection was a unique experience for the staff and students involved. We were able to accomplish this project economically, without the use of expensive microscopes and cameras. Therefore, we strongly urge other seed banks to increase the visibility of their collection through imaging and online availability.

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Achieving better outcomes from seed bank Data Management systems

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Introduction

There are many key activities that contribute to the successful management of a seed or gene bank. One such activity is data management. In undertaking research and collection management activities data are generated. The analysis and synthesis of this data help answer the questions such as how to achieve successful banking of seed, seed germination or alleviating dormancy. The data can also provide information about species characteristics to help understand their climate adaptability, or to inform ecosystem restoration.

This data encapsulates the knowledge and skills of the researchers, curators and technicians who contribute to it. To maximise the impact, data itself must follow the FAIR principles – be Findable, Accessible, Interoperable and Reusable. Furthermore, in a resource constrained environment organisations need to leverage skills in a collaborative way to avoid duplication of effort, provide timely outputs and maximise skills. The National Seed Bank (NSB) systems have been developed with these principles and objectives in mind. This article will present the approach and methods used to deliver better outcomes for the internal business systems and integration to national and international databases.

Approach

Leading up to 2012 a project was undertaken at the Australian National Botanic Gardens (ANBG), Canberra to bring together siloed systems that served the herbarium, seed bank and living plant collections. Work was undertaken to analyse and prepare a data model and an associated application which would combine these datasets and meet a number of principles, these being:

1. Enter data once and share – common data about the collection such as what do we have (stock), where is it (inventory), where was it collected and by whom (provenance) and what is its scientific name (identification) would be shared between herbarium, living and seed collections. This principle is also embedded in the objectives of the Centre for Australian National Biodiversity Research (CANBR) collaborative agreement between the Director of the National Parks (DNP) and CSIRO.
2. Support data and processes for specific areas – for the seed bank this included germination trials, seed pre-processing, characteristics such as thousand seed weight, or storage conditions. The model had to be adaptive with the ability to adopt innovations and additional data into the future.
3. Support analysis and decision making.
4. Adhere to FAIR principles – the data must be Findable, Accessible, Interoperable, and Reusable.
5. Adhere to international exchange standards such as Darwin Core to facilitate exchange of data between institutions such as the ANBG and the Millennium Seed Bank, Kew, and to aggregators such as the Atlas of Living Australia (ALA).
6. Adopt common patterns to reduce the IT overhead of introducing new methods and processes where possible (data and configuration over programming).

Implementation

This analysis led to the data model Figure 1 which became the basis of the database built to support the combined herbarium, living collections and seed bank. Much of the model which handles provenance,

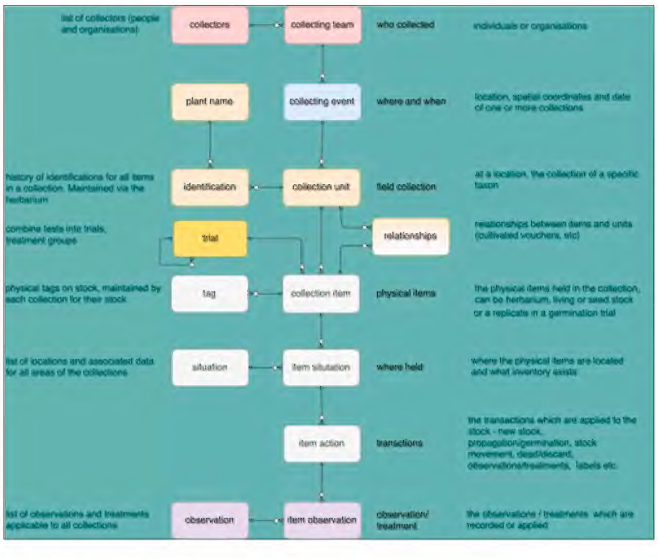


Figure 1. Data Model.

Basic data structure for generic management of observations/treatments

OBS_CATEGORY	OBS_GROUP	OBS_TYPE	OBS_CODE	MEASUREMENT_1	UNIT_OF_QTY_M1	MEASUREMENT_2	UNIT_OF_QTY_M2	DESCRIPTION
Treatment	Propagation	Substrate	AGAR%		%			AGAR concentration
Treatment	Propagation	Substrate	Soil					Soil mix used for seed trial
Treatment	Propagation	Substrate	Filter paper					Filter paper.
Treatment	Propagation	Substrate	Towelling					Towelling.
Treatment	Propagation	Substrate	Moss					Moss
Treatment	Propagation	Substrate	AGAR+KN04					AGAR base with potassium nitrate added.
Treatment	Propagation	Substrate	Filter/towel					Filter/towel.
Treatment	Propagation	Substrate	AGAR+GA3	200	ppm			AGAR base with gibberellic acid added.
Treatment	Propagation	Chemical	H2SO4%		%		hours	Soaked in Sulfuric acid (H2SO4) at concentration for a period
Treatment	Propagation	Chemical	GA3sub		ppm			Gibberellic Acid applied to substrate at a concentration.
Treatment	Propagation	Chemical	KN04soak		ppm		hours	Soaked in potassium nitrate at a concentration for a period.
Treatment	Propagation	Chemical	GA3soak		ppm		hours	Soaked in gibberellic acid at a concentration for a period.
Treatment	Propagation	Chemical	KN04sub		ppm		hours	Potassium nitrate applied to the substrate at a concentration.
Observation	Seed Sample	Purity	PctPurity		%			% Purity.
Observation	Seed Sample	SW	SW		gm			Sample weight of seed (basis of TSW-m2 calculation)
Observation	Seed Sample	TSW	TSW-m1		gm			Thousand seed weight calculated from one sample.
Observation	Seed Sample	TSW	TSW-m2		gm			Thousand seed weight calculated from an average of 5 samples.
Observation	Seed morphology	Appendage	seed appendage					Seed appendages
Observation	Seed morphology	Length	seed length		?		?	Calculated length of seed (average, standard deviation) in microns
Observation	Seed morphology	LengthSample	seed sample(length)		ea			Number of seed used in length calculation

User entered values

Figure 2. Observation and Treatment examples.

occurrence and identification data was already well established and are able to be mapped to the Darwin Core biodiversity standard.

However, seed banks have several additional requirements which required an extension to these core data. Data associated with activities such as germination trials, testing results, pre-processing, standard seed bank metrics such as thousand seed weight and tracking of storage conditions lead to a design in which a generic model based on observations and treatments was adopted. An observation is something which is 'seen' and a treatment is something that is 'done'. These terms are a convenience to help categorise different codes assigned for data entry. Examples of this approach are presented in Figure 2. Overtime the list of codes has been extended to handle new requirements such as recording the morphological characteristics of seed derived from microscope images, the inclusion of a new x-ray test for seed fill and categorising seed storage behaviour (orthodox or otherwise). This ability to extend the application for new data with minimal programming is important for adoption of new methods in a timely way without extensive outlay of information technology resources.

In the seed bank application, to streamline data entry, reduce errors and support reporting requirements, the basic reference table for observation/treatment allows for two additional levels of categorisation, a unique code and two pairs of values (value, unit of qty) which can be associated with frequently used characteristics or test conditions. A more generalised model would provide ultimate flexibility however based on the analysed reporting requirements this level of categorisation has worked for our application.

The other feature of the data model and application is that it uses a set of inventory management tasks to track the stock quantities and location through 'actions' such as accessioning of new collections, recording the location and movement within the collection, how it leaves the collection – as a donation to another institution, deaccessioned, or consumed in germination trials.

This is coupled with 'the story' of the seed through its scientific journey – the observations and treatments made upon it – how it is pre-processed for storage, images are taken and characteristics measured, x-rays are taken to measure seed fill, seed is germinated in trials and the steps are recorded – the pre 'treatments', the trial conditions (day/night photoperiod, substrate), germination results, any re-treatments required and the

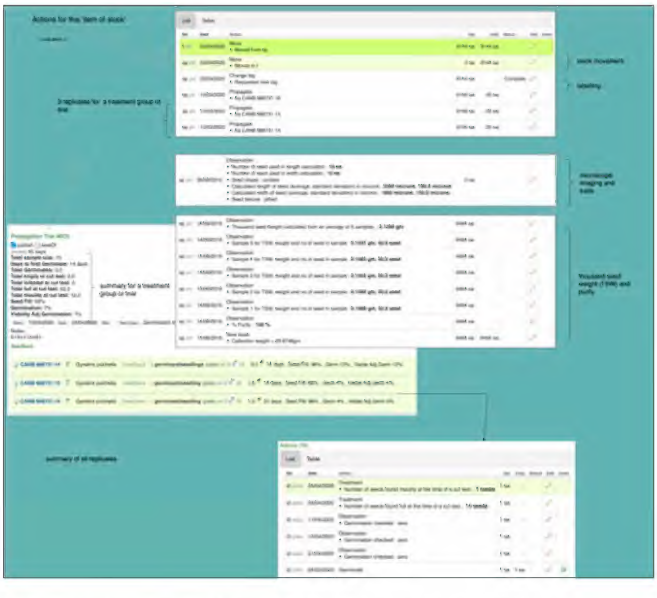


Figure 3. Data entry of inventory and science actions.

final cut tests. This mixture of inventory management and observation provides a flexible data set to meet reporting and analysis requirements. Examples of how inventory and science data is recorded is presented in Figure 3.

Supporting Seed Science

How do these data support seed science? By recording primary data, as opposed to summary results, and recording details relating to the data's origin (who created the record, when and through what action), this model provides the ability to report, collate, analyse, and export the data to support the activities of the seed bank both for management of the collection and contributing to scientific knowledge and sharing data.

Synthesis of this data allows a summary to be presented in real-time in the data entry system providing a quick overview of the data for a seed collection. The summary presents characteristics of the collection such as purity and seed fill, a snapshot of the seed's morphology and available microscope images, and germination statistics for each test that has been undertaken to quickly review germination results (Figure 4).

In addition to the seed science data, the inventory management aspect of the system and any related data from the living collection and herbarium can be presented in a consolidated view (Figure 5) which puts all related data at the user's fingertips.

To supplement presentation in the data entry system, standard outputs and exports from the data are provided. Scripts have been written to generate required reports or views of the seed bank data. Each script can be run for various parameters which allows the data to be reported pertinent to the questions *e.g.,* which seed collections had a germination test in a particular year and what was the result?, what are the results of germination tests undertaken for *Eucalyptus rossii*? The output of each script can be downloaded to Excel for further work. These statistics are generated on the base data which allows, over time, for the data to be analysed in different ways.

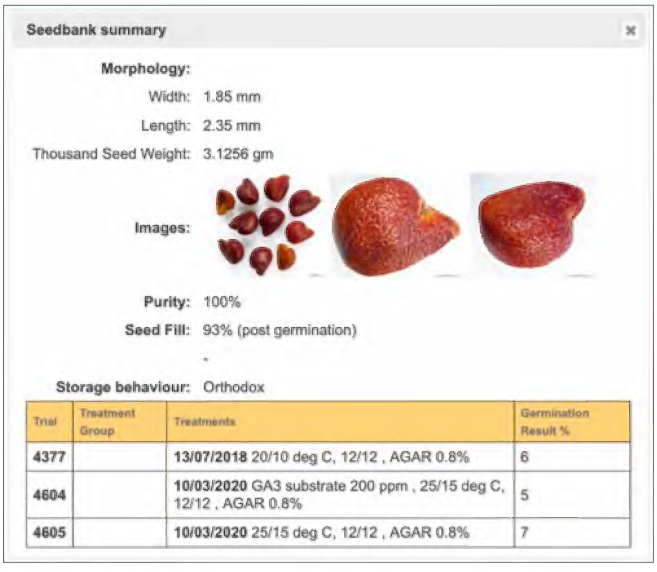
An overview of the analysis, exports and potential usages of some of the seed bank data is presented in Figure 6.

Specific examples of reports currently generated from the system include:

Analysis

Germination trial outcomes

Provides a summary of all results for a germination trial with data on number of replicates, total number of germinates; number of empty, mouldy, full seeds after cut-test; % seed fill, final %germination, %viability adjusted germination, days to first germination and total number of days in the test. This can be requested based on a number of criteria such as a taxon name to compare tests for different collections of the same taxon.



Trial	Treatment Group	Treatments	Germination Result %
4377		**13/07/2018** 20/10 deg C, 12/12 , AGAR 0.8%	6
4604		**10/03/2020** GA3 substrate 200 ppm , 25/15 deg C, 12/12 , AGAR 0.8%	5
4605		**10/03/2020** 25/15 deg C, 12/12 , AGAR 0.8%	7

Figure 4. Seed Collection Summary.

Figure 5. Consolidated view of shared data services.

Testing and viability schedules

Collate data to support the scheduling of seed testing programs – when was the seed originally collected?, what germination testing has occurred?, has any previous testing resulted in a 'successful' germination test (>75%)? The data collected from all previous tests and general provenance data are used to report the current status and help inform decision making. This is supplemented with analysis of the storage conditions of the seed – how long has it been stored under different conditions, age of the seed and linked to previous germination testing results.

Data gap analysis

Assess the seed collection to identify those collections which do not have all the required seed bank metrics. This is done by reviewing whether germination testing has been conducted, that the seed has been weighed and a thousand seed weight has been recorded. This allows work to be scheduled within seed bank resources to ensure minimum levels of collection and data quality.

Annual reporting

Collate statistics for annual reports such as numbers of new seed collections, and through matching the seed bank data to other datasets such as the Species Rare and

Threatened (SPRAT) provide the number of collections of EPBC priority taxa and overall percentage of EPBC priority taxa represented in the collection.

Data Exchange

To support the exchange of data to other data aggregators, institutions or researchers the FAIR principles must be met. A large part of ensuring this principle is adoption of existing biodiversity standards such as those provided by the Biodiversity Information Standards (TDWG). In the biodiversity community standards for occurrence data are well articulated, such as Darwin Core, and form the basis for delivery of occurrence and related data to products such as the Australian Virtual Herbarium (AVH).

However definitions and standards for the exchange of seed bank characteristics are a work in progress and are being addressed via workshops such as the Seed Trait Workshop, Perth, 2016 (Saatkamp *et al*. 2019), in the proposed Seed Germination Database (pers. comm. 2022) and work by ALA and Global Biodiversity Information Facility (GBIF) piloting changes to the current Darwin Core and extensions (pers. comm. 2022). The implication of this is that the standards for the exchange of trait data are a work in progress.

The approach taken to date is to adopt a standard where it is available and where not, adhere as much as possible to an existing standard but with a focus of delivering the data required for shared seed banking and research. As biodiversity standards for this data mature they will be adopted.

Australian Seed Bank Partnership (ASBP)

The ASBP mission is a national effort to conserve Australia's native plant diversity through collaborative and sustainable seed collecting, banking, research and knowledge sharing. The NSB support this mission in multiple ways including through the provision of data to the Australian Seed Bank online portal hosted at the Atlas of Living Australia (ALA).

On the inception of the ASBP project in 2011 one of the first tasks was to prepare a data exchange standard (ASBP Shared Data Definitions v0.2) which meet the above principles but also considered various levels of raw and summarised seed bank data available in different institutions. The NSB has provided data, using these standards, to the ASBP on an ad-hoc basis since December 2012.

AusTraits

AusTraits is an open-source, harmonised database of Australian plant trait data and integrates plant trait data collected by researchers from diverse disciplines, including functional plant biology, plant physiology, plant taxonomy, and conservation biology (Falster *et al*. 2021). The NSB contributes data to this project using the same data exchange files as provided to ASBP, providing reusability and common data to both aggregators.

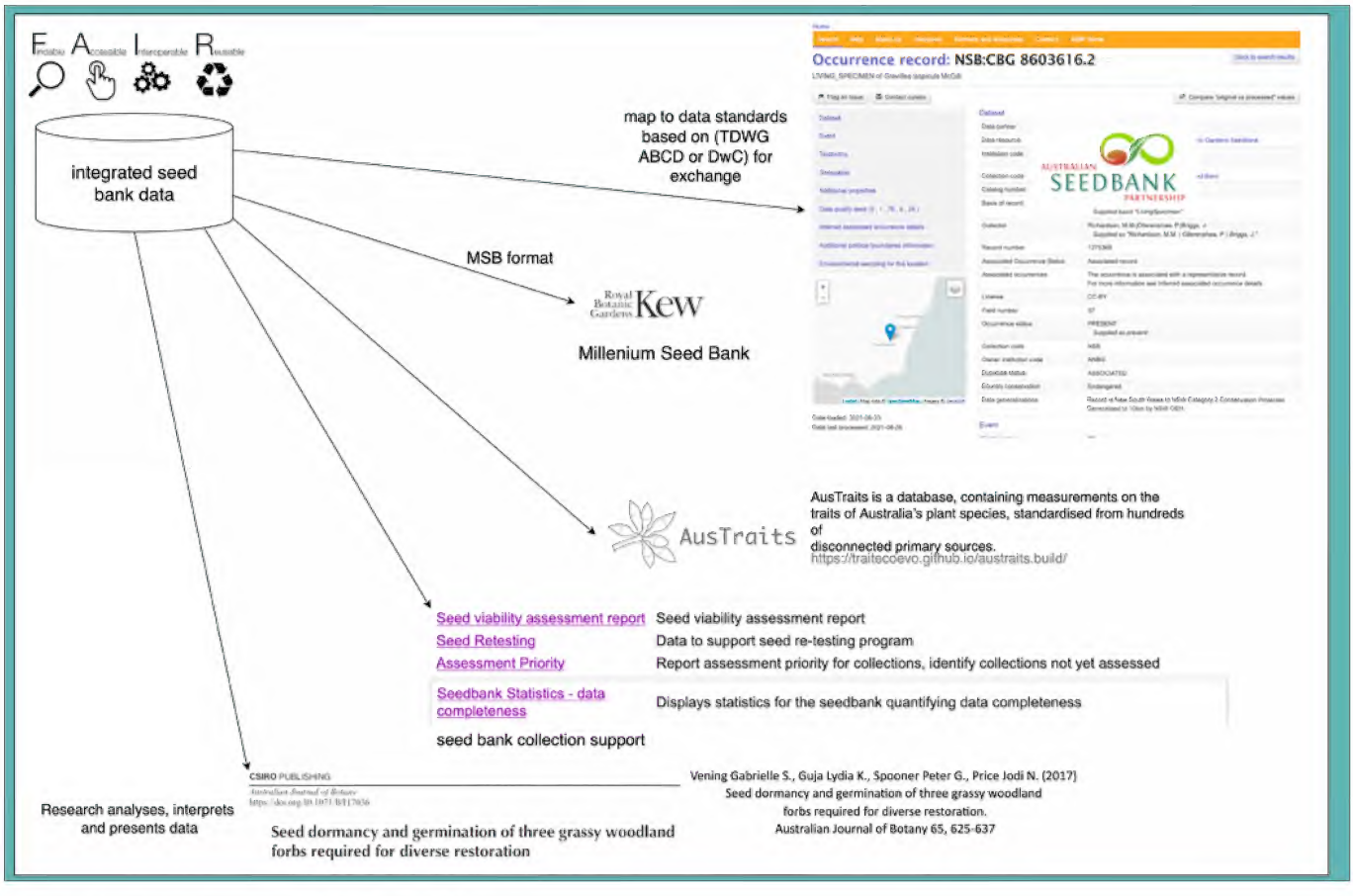


Figure 6. Analysis, exchange and FAIR use of data.

Conclusion

The adoption of robust data structures that have proven adaptable to new requirements, with minimal programming effort, have allowed the seed bank to quickly implement new methods and procedures and capture the data electronically. This has allowed standardised reports to be created to support management of the collection and the sharing of seed science data. From the standard data inputs information can be provided to service different requirements at different scales, for example informing the seed bank team's curation and research work, the ANBG's living plant collection maintenance, the national picture of conservation collections or plant traits and the global understanding of seeds and biodiversity.

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Websites

Atlas of Living Australia https://ala.org.au

Australian Seed Bank Partnership https://www.seedpartnership.org.au

Australian Seed Bank online https://asbp.ala.org.au/

Australian Virtual Herbarium https://avh.chah.org.au/

AusTraits https://austraits.org/

Global Biodiversity Information Facility (GBIF) https://gbif.org

TDWG https://www.tdwg.org

Darwin Core https://www.tdwg.org/standards/dwc/

News from the ASBP

Extract from the Partnership's Annual Report 2021–22

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The Australian Seed Bank Partnership are pleased to share highlights from over the last year.

The Western Australian Seed Centre, Kings Park

Over the course of 2021–22, field collection activities included trips to Western Australia's Mid-West Region, Stirling Range and Kimberley as well as various day trips made in the areas surrounding Perth. With 45 days spent in the field, 186 collections of 122 species were made, most of which have now undergone germination testing and are safely stored in the seed bank as conservation collections. These are also now available for use in research activities. Collections were made across a broad cross-section of the species' ranges to gather a suitable representation of the genetic diversity within a species, and future collecting activities will focus on increasing the number of populations from which the seeds are sourced.

With the benefit of additional funding made available by the Australian Seed Bank Partnership through the UK Government Emergency Bushfire Fund, Kings Park was able to send a team of four staff to collect within bushfire-prone areas of Western Australia's Stirling

***Eucalyptus lehmannii* subsp. *parallela*, Stirling Range National Park. Photo: Matthew Stray**

Range National Park over five days. A highlight of this trip was the collection of seed of the Dwarf Kangaroo Paw (*Anigozanthos gabrielae*), which is a beautiful little perennial plant that grows in sand, throughout winter-wet areas in southern Western Australia. This plant has become a showstopper when on display within the botanical garden in recent years, but over time the quantity of seed available for propagation has dwindled.

Other noteworthy and highly ornamental species collected on this trip included *Eucalyptus lehmannii* subsp. *parallela, Beaufortia decussata* and *Verticordia pennigera*. In total, this successful trip yielded more than 30 collections which have now been processed, X-rayed and germination tested, with all relevant data recorded. The germination data will soon be made available for use by seed bank partners and hopefully inform and build upon future research and conservation initiatives taking place in the region.

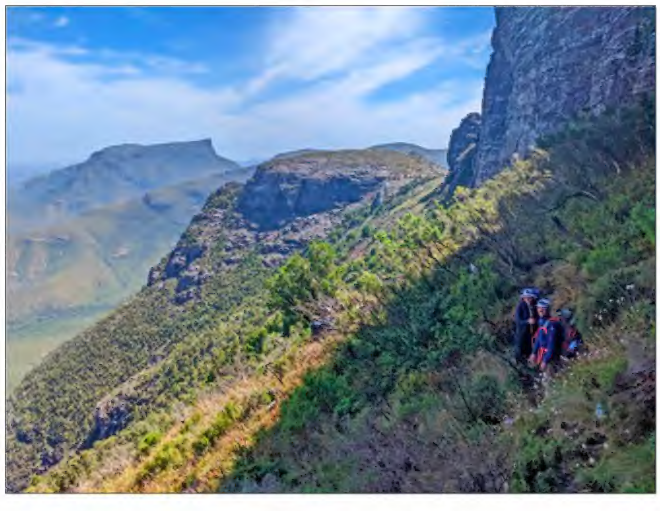
The Western Australian Seed Centre, Kensington

Rising out of an otherwise flat landscape, the mountains of the Stirling Range National Park provide a distinctive geological feature in the south-west of Western Australia. This unique location is home to an incredible diversity of plants; over 1,500 species, more than 80 of which are endemic to the park. The higher reaches of the eastern peaks (> 900 m altitude) are recognised as a Threatened Ecological Community (the Eastern Stirling Range Montane Heath and Thicket) and are home to a dozen threatened plant species and numerous other plants of conservation significance. This eastern range is also the location for what is regarded as one of Western Australia's most spectacular but also most difficult walks, the Stirling Ridge Walk. This walk follows the mountain ridges from Ellen Peak in the east, to Bluff Knoll (the highest peak in southern Western Australia), to the west.

A few years ago, two fires, one in Autumn 2018 and one on Boxing Day 2019, had resulted in more than two thirds of the park being impacted by fire. The areas affected included the montane ecological community and the threatened species it contains. To assist these species in their recovery, a concerted management effort has been underway including post-fire surveys to help understand species' response to fire, seed collection and translocation.

Thanks to bushfire recovery funding obtained from the UK Government by the Australian Seed Bank Partnership, seed collections were made from a number of these threatened species. Over the summer of 2021–22, staff from the Western Australian Seed Centre, Kensington, made numerous trips to the park, including its highest peaks, seeking unburnt populations, then bagging fruit as they formed to allow seed collection later in the season.

The culmination of this work was a three-day expedition following the route of the ridge walk and retrieving seed that was bagged on earlier trips. What can already



Staff on the Stirling Ridge Walk below Pyungorup. Photo: Megan Dilly

be considered a challenging walk—due to the difficult terrain, extreme weather conditions and the need to carry all of your required water—was made even more difficult thanks to the additional equipment required when making *in situ* seed collections. The team managed to secure 15 seed collections of six threatened species and an additional five collections of conservation significant species. The bulk of the seed will be stored for safekeeping in the vault at the Seed Centre. However, for some of the species, seedlings produced from germination testing of the collections are destined to augment existing plantings in two seed orchards. These seed orchards aim to bulk the quantities of seed available to facilitate future recovery of these unique and highly threatened Stirling Range species.

South Australian Seed Conservation Centre

In a bid to safeguard Kangaroo Island's threatened flora from extinction, the South Australian Seed Conservation Centre has been working to launch a Threatened Flora Seed Production Garden at the Cygnet Park Sanctuary. The 5,000 m^2 herbivore-proof exclosure will host more than 60 of the island's at-risk species and will allow future seed collections for banking and biodiversity recovery projects on the island. A collaboration between the SA Seed Conservation Centre, the Nature Conservation Society of South Australia and BioR, the garden will contain tailored habitats to mimic the conditions found across various parts of the island. These include a range of soil types, rocky outcrops, wetland areas and ponds.

Over 1,500 plants have been propagated for the garden by botanists at the SA Seed Conservation Centre, which will be planted out by Kangaroo Island community members and project partners in July 2022. To ensure the garden's success, a 'Friends of KI Threatened Flora group' will be formed, upskilled and mobilised to collect seed, monitor plants, propagate and translocate species from the garden to the wild, giving the island's natural habitat a biodiversity boost. Support for this initiative has been provided through:

- the Nature Conservation Society of South Australia's 'Mobilising and Supporting a Community Led Fire Recovery for Kangaroo Island's Threatened Flora' project—funded by the Landcare Led Bushfire Recovery project
- the Australian Seed Bank Partnership's 'Island, Alps and Forests' project—funded by the Australian Government's Bushfire Recovery Program for Wildlife and their Habitat
- the Paton family's contribution of land to Cygnet Park Sanctuary
- BioR and the Nature Conservation Society of South Australia providing project assistance
- garden concept designs by Troppo architects
- SeaLink providing passage to and from Kangaroo Island.

Once established, the garden will be a hub for exciting conservation outcomes in the years to come. Photo: Troppo Architect

The Victorian Conservation Seedbank

This past year has been another busy one for the Victorian Conservation Seedbank (VCS), whose staff undertook 13 trips throughout the summer, making more than 90 seed collections. One of the most significant collections was of a very rare *Commersonia*. This species was first observed in December 2020 while botanists from the VCS were out on the Genoa River in East Gippsland undertaking species assessments and seed collecting as part of Project Phoenix.

***Commersonia rugosa* fruiting along the Genoa River in East Gippsland. Photo: Andre Messina**

During a search for *Pomaderris helianthemifolia* subsp. *hispida*, we discovered a small population of this unknown *Commersonia*. Members of this genus are quite rare in Victoria and often only seen following disturbance, such as after fires. So, despite not knowing which species it was, we were sure it would be a significant find.

Plants were sterile, so cuttings were taken and grown on at the Royal Botanic Gardens Victoria. In October 2021, plants in the nursery produced fruit, providing all the features needed for identification. We were then able to establish that plants were *Commersonia rugosa*, a species not previously recorded in Victoria. This is the fourth species of *Commersonia* recorded in Victoria, three of which are only ever seen following fire and known from only one or two sites.

In December 2021, less than two months after establishing the identity of these plants, we returned to the spot on the Genoa River and collected seed from this population as part of the Partnership's 'Island, Alps and Forests' project. During this work we were able to find eight plants in two small clusters on a rocky river terrace, making this one of the rarest and most enigmatic species in Victoria. We were able to collect seed from six plants which are now secured in long-term storage at the VCS.

Tasmanian Seed Conservation Centre

Work carried out in the Tasmanian Gell River area this year proved to be very fruitful, with six species collected from the ridgeline of The Needles, located in the north-west tip of the Southwest National Park. Most notable among the collections was a recollection of the endemic *Anemone crassifolia*, which proved to be more successful than the previous season, with 4,800 seeds harvested. Other species collected were *Stylidium graminifolia* and the charismatic endemics *Blandfordia punicea*, *Dracophyllum milliganii*, *Isophysis tasmanica* and *Campynema lineare*.

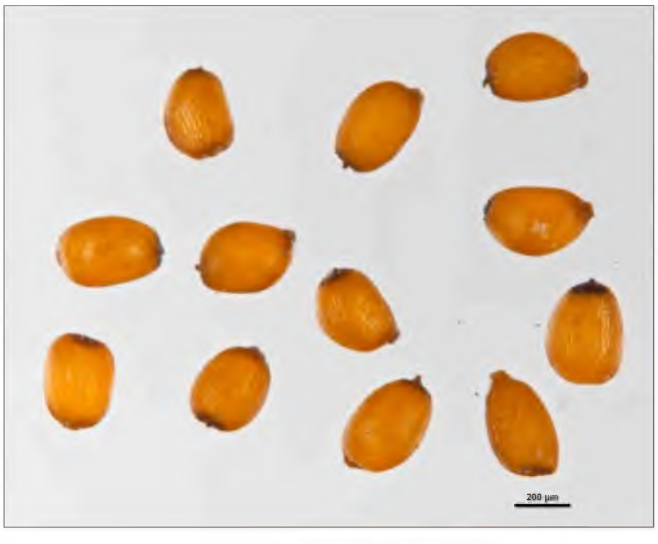
***Dracophyllum milliganii* flowering on a burnt hillside in the Southwest National Park. Photo: James Wood**

Collecting and surveying work on the Central Plateau uncovered a new population of the rare *Euphrasia scabra*. This was the first record for this bioregion since 1981, and 12,000 seeds were harvested from this new population. Also notable was a collection of 14,400 seeds of the endemic *Coprosma moorei*, following a tip-off of a heavily fruited, large population near Lake Mackenzie. This species is typically problematic as the fruit only holds a maximum of two seeds and the populations typically tend to be small and very scattered. The *Coprosma* population was found during the monitoring of a Pencil Pine replanting trial. The area was consumed by fire back in 2016 and had destroyed stands of the fire-vulnerable pine. Trials are being conducted to see whether the pines can be successfully reintroduced, using seed collected by the Tasmanian Seed Conservation Centre. It was a novel and rewarding experience collecting seed among young plants established through previous work.

National Seed Bank

One of the highlights at the National Seed Bank this year was the successful collection and germination of *Dracophyllum oceanicum*; a shrub species restricted to a small part of the Jervis Bay area in New South Wales. Collecting and germinating this species was significant, as historical botanical descriptions indicated seeds had not been observed and the species may be sterile. The seed collections mark the first time this species has been represented in an Australian seed bank and ensures that this species is safeguarded into the future.

Dracophyllum oceanicum plants around the Jervis Bay area and at Booderee Botanic Gardens were netted to catch falling seed. This resulted in three small collections, totalling 200 seeds. The dust-sized seeds had to be carefully handled, with debris and chaff meticulously removed from the collections under a microscope.



***Dracophyllum oceanicum* seeds collected from coastal cliffs. Photo: J. Fitz Gerald**

Seed was then X-rayed to ensure the seeds were filled, before a tetrazolium staining test was conducted to check whether the seeds were viable. All collections were found to be viable, and the seeds germinated readily under standard conditions. Germinated seeds have been transferred to Booderee Botanic Gardens at Jervis Bay where they will be grown and used for future seed collections.

Seed collections of *Dracophyllum oceanicum* were made possible by funding from the UK Government to support plant conservation after the 2020 bushfires. Because of this funding, the National Seed Bank has been able to collect, store and research the germination requirements of several species that have been bushfire affected or that inhabit areas that are at risk of future fires.

The Australian PlantBank

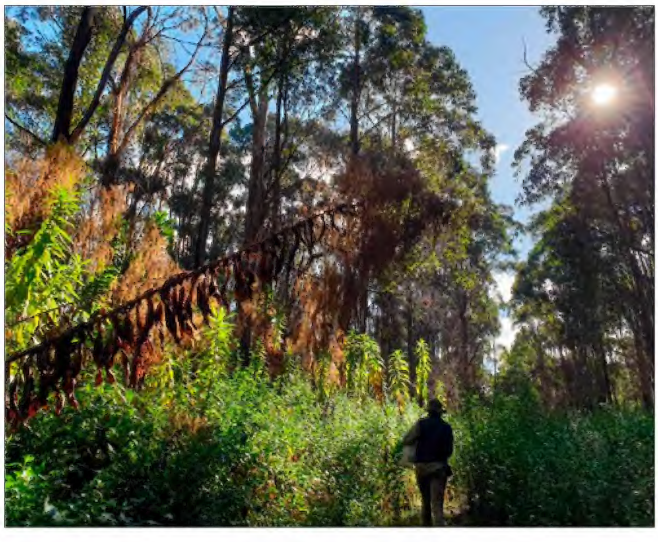
The PlantBank team have witnessed some impressive regeneration of native plants out of the ashes of the 2019–20 summer fires. A spectacular and aromatic plant that germinates prolifically after bushfire is the Incense Plant, *Calomeria amaranthoides*, which is a biennial herb from the daisy (Asteraceae) family and which has been flowering and fruiting profusely this season in fire-disturbed areas, like road verges, south from Hexham. The reddish plume of their inflorescence can be seen from quite a distance. The PlantBank team stumbled across a large population of this species in Nadgee Nature Reserve while searching for the more elusive *Hibbertia notabilis*—however it was not then producing seed. The area had been severely burned by the fires, but is now thick with regenerating plants. When returning to the site six months later to collect the bags from *Hibbertia notabilis*, the team could not resist making a seed collection of this stunning two-metre tall *Calomeria*, which can be seen in the photos dwarfing seed collector Lily.

The Queensland Herbarium

The Queensland Herbarium has teamed up with Quandamooka Yoolooburrabee Aboriginal Corporation (QYAC) to survey and collect seeds from the endangered Swamp Daisy, *Olearia hygrophila*, as a part of the Australian Seed Bank Partnership's 'Island, Alps and Forest' project.

The Swamp Daisy is a highly restricted rare plant from Minjerribah (North Stradbroke Island) and is the only known endemic plant species from the island. As its common name suggests, it occurs in dense coastal swamps *of Melaleuca quinquenervia* and *Eucalyptus robusta*, with species of *Gahnia* dominating the ground layer. The species appears to be highly dependant on groundwater for survival and seems unable to tolerate soil desiccation. Access to a high water table therefore appears essential to its survival. Swamp Daisy is known to persist only at one location while being ephemeral at several others.

In collaboration with QYAC and with the assistance of QYAC Rangers, active steps have been taken to ensure this species' ongoing survival. This work so far has involved surveying sites where the species currently exists and in locations it was previously recorded, collecting seed for ex situ conservation, and DNA sampling for future investigations into population genetics. The work has enabled invaluable data to be gathered on current population size, the number of locations where it currently occurs and the threatening processes faced by this endangered species. This information is currently being utilised to prepare a new threatened species assessment on *Olearia hygrophila* under the Common Assessment Method.



PlantBank staff surrounded by *Calomeria amaranthoides* foliage at Nadgee Nature Reserve, New South Wales. Photo: Laura Watts

Collecting the Swamp Daisy (*Olearia hygrophila*) on Minjerribah. Photo: Jason Halford

Australian Network for Plant Conservation

The fully revised 3rd edition of 'Plant Germplasm Conservation in Australia' (the Germplasm Guidelines) was launched in September 2021 at the Australasian Seed Science Conference, as a joint publication of the Australian Network for Plant Conservation and the Australian Seed Bank Partnership, funded by The Ian Potter Foundation. The Germplasm Guidelines are a resource for sharing knowledge of seed banking and other forms of ex situ plant conservation, which helps safeguard plant diversity for future use in restoration, translocation, horticulture and research. The guidelines are practical, technical and evidence-based, providing a workflow to address each step of acquiring, maintaining and utilising genetically representative collections.

They bring together decades of research and experience from 78 contributors actively conserving Australian plants in seed banks, botanic gardens and conservation nurseries. They take readers through the genetics and practice of acquiring collections and the processes of seed banking, tissue culture, cryopreservation, and living collections maintenance, along with 50 case studies to highlight the application of research and theory.

This edition is a testament to the increased understanding of the Australian flora, with mentions of more than 116 genera and 117 plant families. The Germplasm Guidelines include information on common plant families, including those known to be difficult to store and germinate. They address the need to collect, store and grow plants with 'special' life history stages or growing requirements and 'special' types of germplasm.

The Germplasm Guidelines have been downloaded more than 700 times and are being incorporated into conservation management and policy documents nationally. A resource pack is now available at https://www.anpc.asn.au/germplasm-guidelines-review/ including a video series and webinar recordings available on the Australian Network for Plant Conservation's YouTube channel.

Australian Seed Bank Partnership Secretariat

To raise awareness of The Rare Bloom Project™, Botanica and the World Wide Fund for Nature (WWF-Australia) opened a pop-up boutique over 28–30 April 2022. Located at The Rocks in Sydney, the 'Rare Bloom Florist' showcased handcrafted paper flowers made by Jo Neville, as well as a series of unique vases painted by Shelby Sherritt, Brooke Styles and Rachael Sarra. These pieces were inspired by the more than 30 threatened wildflowers that were secured during the first year of the project. A silent auction allowed visitors to bid on the different pieces, with all proceeds donated to WWF-Australia to contribute towards the project. With over $2,500 raised, this funding will go towards a Partnership scholarship in 2023 that focuses on seed-related research and supports the conservation of Australian flora. The scholarship will support an early- to middle-career researcher, or a student completing an Honours/Masters/PhD project in one of our Partnership facilities.

Paper flowers and vases from the Rare Bloom Florist Pop-up. Photo: Damian Wrigley

Assessing impacts and recovery after the 2019/2020 fires of priority plant species that were not previously threatened

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Background

The extensive fires in south-eastern Australia in 2019/2020 burnt a number of plant species (and their habitats) that were not considered threatened prior to the fires. This has the potential to increase the risk of those species becoming threatened in the near future should factors relating to the 2019/2020 fires or other threats lead to decline. A range of factors will determine the ability of these species to successfully recover after the fires. This includes the separate and cumulative effects of fire severity, fire frequency, ongoing drought and a changing climate, along with direct biotic threats such as impacts of post-fire grazing by feral animals and stock, weeds, and pathogens. The IUCN Red List criteria for species identify different mechanisms by which species may be threatened with extinction and can be applied to species impacted by the 2019/2020 fires.

In 2020, the San Diego Zoo Wildlife Alliance (SDZWA) Plant Conservation Team provided funding to the ANPC to support plant conservation actions aligned with the recommendations of the Federal Threatened Species Scientific Committee (TSSC) for Post-fire Recovery to: 1) Prevent extinction and limit decline of native species and ecosystems affected by the 2019-20 fires, and 2) Reduce impacts from future fires.

Progress to date

There are three main components to the project:

1. Support for development of a nomination for 'Fire regimes that cause biodiversity decline' as a Key Threatening Process (KTP) under the national Environment Protection and Biodiversity Conservation Act (EPBC Act).

Funding has supported (in combination with other funding sources) the assessment and preparation of this KTP document under the EPBC Act. The KTP nomination was completed in collaboration with experts from the TSSC, was endorsed by that expert Committee, and was released for public comment in December 2021. In April 2022, then Minister for the Environment, Sussan Ley, formally announced the KTP listing under the Act (https://www.dcceew.gov.au/environment/biodiversity/threatened/key-threatening-processes/fire-regimes-that-cause-declines-in-biodiversity).

The project funding also helped develop guidance on recovery actions to build the resilience of biota to future fires, through lead authorship of a major technical report (Department of Agriculture, Water and the Environment, 2022), and contributed to three journal articles: Zylstra (2021); Zylstra *et al.* (2022a) and Zylstra *et al.* (2022b). These articles were aimed at building the human contribution to the resilience of biota to future fires by quantifying the mechanisms of risk and investigating new approaches to reduce the incidence of future fires (Figure 1).

2. Impacts of 2019/2020 fires on selected priority plant species

Gallagher (2020), Gallagher *et al.* (2021, 2022) and Auld *et al.* (2020) identified species of national significance in Australia that were potentially adversely impacted by the 2019/2020 fires. Gallagher *et al.* (2018) and Le Breton *et al.* (2019) identified those species not currently recognised as threatened, that had geographic range sizes that are below the thresholds in IUCN Red List Criterion B. A combination of these sources allowed us to create a priority list of species for field inspections to identify factors threatening recovery after fire for species with restricted geographic range sizes. Unfortunately, the field surveys have suffered from significant delays in 2020 and 2021 due to COVID-19 lockdowns and travel restrictions, and more recently (first six months of 2022) from road and track closures due to heavy rainfalls and flooding in eastern Australia.

Figure 1. Understorey dynamics in Jarrah forest exemplify the drivers of fire risk measured in Zylstra *et al.* (2022). Recently burned Jarrah (A) has a dense understorey of germinated shrubs and saplings that burned seven times more frequently than the same forest left unburnt for around 50 years, which develops an open understorey (B). Processes of growth and forest succession such as self-thinning and self-pruning act as 'ecological controls' on wildfire spread and severity (Zylstra *et al.* (2022a). Photos: Philip Zylstra

Two groups of taxa were chosen:

a. Species were chosen to allow comparisons of those with canopy versus soil seed banks and between resprouting versus obligate seeding plants (Table 1). Obligate seeding species (*i.e.,* those killed by fire) with canopy seed banks are thought to be most at risk from high frequency fire or loss of recruitment following the 2019/2020 fires as the seed bank is exhausted in a single recruitment event after a fire. Obligate seeding species with soil seed banks are somewhat at risk as the seed bank declines, but some buffer may be present. Resprouting species are considered likely to be less at risk unless drought conditions have led to increased plant mortality before, during and after the 2019/2020 fires.

   The focus was on NSW endemics, as NSW was the part of Australia most impacted by the 2019/2020 fires, and in order to collaborate with work proposed, or being undertaken, by the NSW Department of Planning and Environment (DPE) and universities on the recovery of other plant species after those fires. Development of standardised field data sheets has been done in collaboration with researchers at the University of New South Wales (UNSW) and DPE. The ANPC is also working with UNSW to undertake IUCN Red List assessments and Conservation Assessments for some of these species.

   A completed IUCN Red List assessment and Conservation Advice has been completed for *Banksia penicillata* based on field work done by Baird and Benson (2021), in collaboration with UNSW.

This recommends that the species be listed as Endangered under the EPBC Act and identifies a number of population declines from the 2019/2020 fires where those fires burnt over areas that had not recovered from a previous fire in 2013 (none of the seedlings from the 2013 fire had matured and produced woody fruits when they were killed by the 2019/2020 fires.) This assessment is now with the Commonwealth TSSC for consideration of listing as Endangered nationally. A Conservation Assessment report for *Banksia paludosa* subsp. *astrolux* (Figure 2) has also been prepared and shows decline in some sites due to very low post-fire recruitment levels.

Figure 2. *Banksia paludosa* subsp *astrolux* is one of the target species being surveyed by the ANPC following the 2019/2020 bushfires. Photo: Tony Auld

Table 1. Species selected for the San Diego Zoo Wildlife Alliance project to assess impacts and recovery after 2019/2020 fires of priority species with restricted geographic ranges that are currently not threatened. R = resprouter; OS = obligate seeder; ? = uncertain response.

Scientific Name	Family	Seed bank type	Response to fire	Risk Drivers (from Gallagher, 2020 and Auld *et al.* 2020)	Who is doing survey/ assessment	Status
Banksia paludosa subsp. *astrolux*	Proteaceae	Canopy	OS	Drought / High fire frequency / Herbivory / Fire severity / Fire sensitivity / Cumulative fire risk	ANPC/ANPC & UNSW	Completed
Banksia penicillata	Proteaceae	Canopy	OS	Drought / High fire frequency / Fire severity / Fire sensitivity / Cumulative fire risk	Experts/ UNSW & ANPC	Completed
Bursaria calcicola	Pittosporaceae	Soil	R?	Drought / Herbivory / Other threats	NSW DPE/ UNSW & ANPC	Waiting for survey results
Darwinia fascicularis subsp. *oligantha*	Myrtaceae	Soil	OS or possibly R	Drought / High fire frequency / Disease / Fire severity / Cumulative fire risk	ANPC/ANPC & UNSW	Completed
Dillwynia crispii	Fabaceae (Faboideae)	Soil	OS?	Drought / High fire frequency / Herbivory / Fire severity / Cumulative fire risk	NSW DPE/ UNSW & ANPC	Completed
Dillwynia stipulifera	Fabaceae (Faboideae)	Soil	R	Drought / High fire frequency / Herbivory / Fire severity	NSW DPE/ ANPC	Waiting for survey results
Grevillea buxifolia subsp. *ecorniculata*	Proteaceae	Soil	OS	Drought / High fire frequency / Herbivory / Fire severity / Cumulative fire risk	NSW DPE/ UNSW & ANPC	Waiting for survey results
Hakea constablei	Proteaceae	Canopy	OS	Drought / High fire frequency / Fire severity / Fire sensitivity / Cumulative fire risk	DPE/ANPC	Waiting for survey results
Hakea macrorrhyncha	Proteaceae	Canopy	OS	High fire frequency / Herbivory / Fire severity / Fire sensitivity / Cumulative fire risk	DPE/UNSW & ANPC	Waiting for survey results
Leptospermum macrocarpum	Myrtaceae	Canopy	R	Drought / High fire frequency / Disease / Fire severity	DPE/ANPC	Waiting for survey results
Leptospermum rotundifolium	Myrtaceae	Canopy	R, but occasionally OS	Drought / High fire frequency / Disease / Fire severity	DPE/ANPC	Waiting for survey results
Leptospermum spectabile	Myrtaceae	Canopy?	?	Drought / High fire frequency / Disease / Fire severity	DPE/UNSW & ANPC	Waiting for survey results
Melaleuca capitata	Myrtaceae	Canopy	R	Drought / High fire frequency / Disease / Fire severity	DPE/ANPC	Waiting for survey results

b. Epiphytic orchids were a group of taxa that were difficult to effectively assess for the likely impacts of 2019/2020 fires as data were lacking. Epiphytic orchids in Australia pose a challenge for conservation assessment for two main reasons: (1) they are commonly affected by taxonomic uncertainty, with boundaries between closely related species uncertain; and (2) they are difficult to survey because they often occur high in trees. Nevertheless, epiphytic orchids were defined as being of conservation concern after the 2019/2020 fires because of their vulnerability to fire impacts, with most species believed to be sensitive to fire/unable to resprout post fire, and reliant on the habitat provided by their host trees (which may have also been damaged or killed by fire). Consequently, a group of such orchids (Table 2) was chosen to examine risk of, in particular, fire severity on plant survival, prioritising species with restricted distributions which included the areas of the 2019/2020 fires. Priority species were identified by Mark Clements, Lachlan Copeland, Bob Godfree and Heidi Zimmer, and this list was further narrowed down to those which could be readily surveyed. Field assessment is being undertaken by Jeremy Bruhl and Lachlan Copeland.

Table 2. Candidates for assessment of impacts of 2019/2020 fires on epiphytic orchids

Species	Family	Distribution	2019/2020 fire impacts
Adelopetalum argyropum syn. *Bulbophyllum argyropus*	Orchidaceae	Currently understood to occur in north-eastern NSW, Lord Howe Island, Norfolk Island and SE Qld, although there is some evidence that island populations may be distinct taxa.	Approx. 50% populations burnt. The main population of this species on mainland Australia was severely burnt.
Tropilis angusta	Orchidaceae	This species exists only in north-eastern NSW and SE Qld (Lamington plateau), but its boundaries with closely related species, including *T. radiata* and *T. aemulum* require further definition.	Some populations burnt. If this species is considered as it is described then up to 100% of its habitat may have been burnt.
Plectorrhiza purpurata syn. *Schistotylus purpuratus*	Orchidaceae	North-eastern NSW	At least three populations severely burnt.
Sarcochilus aequalis	Orchidaceae	North-eastern NSW	At least one population severely burnt.

3. Impacts of Myrtle Rust on plants of Myrtaceae

The ANPC is planning to undertake more post-fire surveys of the impacts of Myrtle Rust on Myrtaceae species, to follow up on our 'Fire and Rust' project from last year (https://www.anpc.asn.au/fire-and-rust/) and complement a separate Commonwealth-funded ANPC project, in progress, to capture representative germplasm of the Critically Endangered Native Guava (*Rhodomyrtus psidioides)*, including from fire-affected regions, as a first step towards assisted recovery of this severely Myrtle Rust-affected species. This latter project is in close accord with the species recovery strategy mapped out in *Myrtle Rust in Australia – A National Action Plan* which was lead-authored by the ANPC's Bob Makinson (Makinson *et al.* 2020).

The ANPC is also supporting and participating in the development of a video on Myrtle Rust (including in the post-fire environment) being developed in Queensland in conjunction with Indigenous stakeholders in south-east Queensland and on the NSW North Coast. This video is now in post-production.

Future work

Field inspections will quantify recovery and identify threats that need amelioration. Funding will be allocated towards postgraduate students or expert field ecologists to focus some of their work on target species in Tables 1 and 2. For other taxa, data from NSW Government surveys will soon be available to allow IUCN assessments to be done. Where a species is considered to meet any one of the IUCN Red list criteria, preparation of a nomination to list the species as threatened will be undertaken. This will entail an assessment against all IUCN Red List criteria and the preparation of an Australian Government compliant Conservation Assessment report (known as a CAM-compliant report). Any species likely to be critically endangered will be prioritised.

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Acknowledgment

This project has been generously funded by the Plant Conservation Team at the San Diego Zoo Wildlife Alliance.

Vale Dr Beth Gott AM

25 July 1922 – 8 July 2022

Editor's note: Instead of a member profile, in this issue of ANPC we pay homage to legendary ethnobotanist Dr Beth Gott, who passed away earlier this year. This tribute was first published by Monash University at https://www.monash.edu/vale/home/articles/vale-dr-beth-gott-am

Renowned ethnobotanist Beth Gott, who has died aged 99, was born to be a scientist. In primary school she recalled explaining to her companions exactly why Father Christmas couldn't exist, due to the lack of empirical evidence.

Instead, the alchemy that excited her took place in the cells and structures of organic matter. From a young age she understood that the survival of humanity hinged on the silent, magical work of plants.

Beth went on to dedicate her working life to botanical research, developing a deep understanding of Victorian Indigenous communities and their thousands of years of plant knowledge. Her research revealed the amazing powers of healing and nourishment that existed in the leaves, stems and roots of plants as well as their capacity for harm (Burke and Wills, for instance, starved to death after eating the Indigenous plant food Nardoo, which they mistakenly believed to be nutritionally adequate.)

Beth was the first person to develop a comprehensive database of Aboriginal plant food knowledge, revealing a huge array of Australian plants that are edible. The plant which particularly captured her imagination was the humble murnong – or yam daisy – a small, dandelion-like plant which at one time was the staple food of the

Image courtesy of the Monash University Archives.

Indigenous people in Victoria. Her 1983 paper on the subject stands as a landmark in Australian ethnobotany for highlighting its importance for the first time.

In 2007, at the age of 84, Beth developed the Aboriginal Garden at the Clayton Campus, containing 150 species of plants, each labelled with its Indigenous name (where known), as well as English and botanical equivalents, and the plant's medicinal, practical or culinary uses. It was a project which began decades earlier after she first arrived at Monash in the early 1980s as a botanist, before being appointed a senior lecturer in botany in 1987. Near the southwest corner of the botany building she planted the first tiny water-ferns with leaves like a four-leaf clover; the seemingly innocent Nardoo.

Though Beth reached the then standard academic retirement age of 65 during 1987, her lectures and practical classes were so enthusiastically received, and her contribution to Monash was seen as so "extraordinary", that her contract was extended at the end of the year.

In 1992 she was made an honorary research associate in the Department of Botany and Zoology and in 1995 became a research fellow after being awarded a grant by the Australian Institute of Aboriginal and Torres Strait Islander Studies.

During her career, Beth engaged in many debates and disagreements with academic colleagues such as ecologists, archaeologists, historians, and scientists and was not afraid to challenge the epistemological foundations of their research regarding the Aboriginal people and their relationship with the land.

In 1989 her work took a forensic twist when she was drawn in to helping solve the mystery of "the body in the bag". Two boy scouts exploring a cave at Springfield Gorge, near Lancefield, discovered the remains of a young Indigenous woman which had been placed in a net bag about 300 years ago. Working in conjunction with the Archaeological Survey and the National Museum, Beth was called in to identify the fibres used to make and tie up the bag. Her painstaking work revealed it was made from the blue flax lily and the inner bark of the wattle.

Beth's prodigious interest in Indigenous culture and the use of native plants had its roots in childhood. Growing up as Margaret Beth Noye in Moonee Ponds she enjoyed listening to stories of Indigenous life from her grandmother who would tell Beth tales of her great-grandfather. He had lived on the Murray River in the very early days of colonial settlement at Swan Hill, and enjoyed very good relationships with Australia's First Peoples.

After leaving school, Beth studied botany at Melbourne University, gaining a BSc in 1942, and an MSc in 1946. In 1951 she was awarded a PhD from Imperial College London, where her initial research topic was the life-cycle of rye cereals. She later continued her work back in Melbourne, studying Australian wheat varieties.

Beth's first husband, Clifford Wilson Serpell, an RAAF navigator, died in an air crash north of Rangoon, Burma (Myanmar) in March, 1944, and the plane and crew were never recovered.

In 1948 at Battersea Registry Office in London, Beth married Ken Gott, a leading activist of the Left, journalist and friend of Overland founder, Stephen Murray-Smith, who, along with his wife, Nita, were witnesses at their wedding. Afterwards they headed to Prague, until they became disillusioned with communism and returned to Australia. The marriage was, in her own words "a meeting of true minds without impairment" and her metaphor for their togetherness was the merging of their libraries.

But Melbourne in the 1950s wasn't an easy place to juggle the roles of academic, mother-of-three and wife. Prams weren't allowed on the trams at peak hour, and Beth had to engage in subterfuge just to get to work. She'd disguise the stroller by stuffing it in a large bag, to confuse the ticket inspector, and board the tram with a child under her arm. When Ken died in 1990, Beth was bereft, initially struggling to find people to talk to, saying "my husband and I were really 'word' people you know".

Beth wrote many papers on the use of Indigenous plants in south-east Australia and taught at universities in the US and Hong Kong before joining Monash. She was guided by a simple realisation; that plant foods and managing the environment were vital to people's survival. As she put it: "you don't live in an environment for thousands of years without knowing how to use it."

Her work corrected many misguided assumptions about traditional Indigenous ways of life. She showed how controlled burning was used to cultivate fresh plants and attract animals, and other land management practices kept their numbers and food resources in balance.

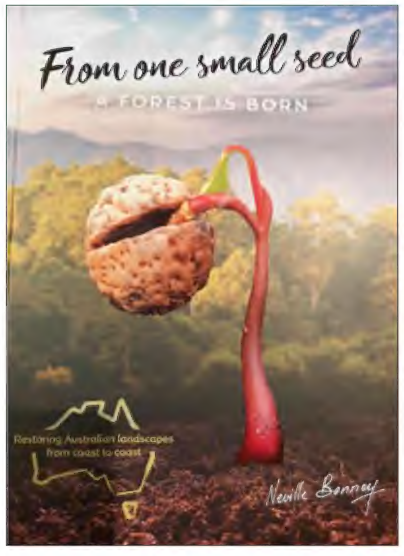
In 2017 Beth was appointed a Member of the Order of Australia (AM) for significant service to the biological sciences as an ethnobotanist. But another title of which she was equally proud was that of "Auntie", bestowed by members of the Indigenous community in recognition of the esteem in which she was held.

Beth continued to work as an honorary research fellow at Monash well into her nineties. "Forget about looking for life on other planets," she would urge, "we have another sort of life here on earth without which we could not survive, so we must value and protect it."

Dr Beth Gott's son, Jim, predeceased her. She is survived by her daughters Margaret and Miranda, her five grandchildren, and by the many who knew and honoured her as an Auntie.

Book review

New book: From one small seed a forest is born



Neville Bonney's book published in 2021 contains a wealth of information on Australian native plants and their seeds. It is the ideal guide for anyone who wants to improve their "seed literacy", particularly those engaged in ecosystem restoration. This book describes 700 Australian native plants and illustrates their flowers, fruits and seeds. information on pollinators, seed dispersal, seed collection, propagation, ecology, Aboriginal names and traditional uses are also included. To purchase a copy contact the author at nbonney@senet.com.au

Reviewed by Chris Fernance

ANPC news

Vale Professor Henry Nix AO (8 July 1937–2 February 2022), the first Chair of the ANPC Advisory Committee

Professor Henry Nix, eminent ecologist, ornithologist, and a major influencer in the Australian field sciences, died earlier this year. Henry was also a key person in the growth of the ANPC.

Soon after the ANPC was formed in 1991–92, an Advisory Committee was established to help maintain and extend co-operation with supportive stakeholders, and to provide guidance for the ANPC's early activities and development of our long-term strategy. The first meeting of the Committee was held in May 1992, and Henry (who was then representing the Association of Societies for Growing Australian Plants) became the first Chair. Henry's ideas, and his encouragement of the ideas of other committee members, made him an important enabler of the ANPC's development. One crucial step promoted by Henry was the incorporation of ANPC, to strengthen its standing among conservation organisations, provide more structure as our activity grew, and to enable us to continue to secure funding in an increasingly regulated environment. This transition was accomplished, and Henry finished his role of Committee Chair in 1998. His role greatly assisted the ANPC to become the organisation it is today. Henry was made a Life Member of the ANPC in 2012.

The ANPC extends the sympathy of all our members to Henry's wife Katherine, sons Simon, Garth, and Jonathan, and his seven grandchildren.

A detailed obituary* covering Henry's whole career, has now been published and is available for free download at **https://www.publish.csiro.au/pc/pdf/PC22006.**

Mark Richardson and Bob Makinson

*Saunders DA et al. (2022). Tribute to Professor Henry Allan Nix AO: pre-eminent biogeographer and ornithologist (8 July 1937–2 February 2022). *Pacific Conservation Biology*, 28(5), iii–vi. doi:10.1071/PC22006

Plants Going Places – Orchids

The final video produced under our Plants Going Places project features a favourite – orchids! With their specialised biology and pollinator specific associations orchids have gained a reputation for being difficult to propagate. This video discusses how to grow and restore orchid populations when faced with many challenges. The video and a podcast were produced by Chantelle Doyle and Michael Lawrence-Taylor under the Plants Going Places project funded by The Ross Trust. Thanks also to the NESP Threatened Species Recovery Hub for their support.

You can find the three Plants Going Places videos on the ANPC YouTube channel. **https://www.youtube.com/watch?v=59-i322sch8&list=PLuPMH5OJZz0GLaO5atuy2Y3tgfXO7CIp3**

All the videos and podcasts from this series and other translocation stories can be found on the Plant Heroes website. **https://www.plant-heroes.com/**

Preventing rare plant extinction

In 2020 the San Diego Zoo Wildlife Alliance (SDZWA) provided funding to the ANPC to prevent rare plant extinction and reduce impacts of future fires.

To date, this project has contributed to:

1. The listing of 'Fire regimes that cause biodiversity decline' as a Key Threatening Process under the national *Environment Protection and Biodiversity Conservation Act 1999*.
2. Creating a priority list of plant species to survey so we can understand factors which threaten their recovery after the 2019/20 megafires. The two groups being focused on are NSW endemics with a narrow range and epiphytic orchids.
3. Supporting surveys to understand the impact of Myrtle Rust on Myrtaceae species after the fires. This work will follow on from our 'Fire and Rust' project last year and complement the 'Safe Custody for Native Guava project' mentioned next. We are also supporting the development of a video on Myrtle Rust which is now in post-production.

More details on the SDZWA project can be found here. **https://www.anpc.asn.au/prevent-rare-plant-extinction-and-reduce-impacts-of-future-fires/**

***Banksia paludosa* subsp. *astrolux* is one of the target species being surveyed following the 2019/2020 bushfires. Photo: Tony Auld**

New project – Safe Custody for Native Guava

The ANPC has partnered with five botanic gardens and the NSW and QLD governments to provide safe custody for the Critically Endangered Native Guava (*Rhodomyrtus psidioides*). This species was not threatened before Myrtle Rust was introduced in 2010 but has since suffered significant declines. This project will provide a coordinated national response to the conservation of this species through germplasm collection, providing resources for maintaining potted collections in conservation nurseries, creating a living collection at botanic gardens in three states and raising awareness through a short video. This project is supported by funding from the Australian Government.

For more information on this project and our partners head to our project webpage. **https://www.anpc.asn.au/safe-custody-for-native-guava/**

Victorian Translocation Symposium

Our Victorian Translocation Symposium had an incredible 299 people register with over a third of this number online during each event. Thank you to everyone who joined us and for all our fantastic speakers, we appreciate you spending your time to share your expertise with our community. If you couldn't join us the recordings for the symposium are now available from the ANPC YouTube channel. **https://www.youtube.com/watch?v=hEkkl0e3Cxc&list=PLuPMH5OJZz0HDnhBdMvOoF8bFBOFT9MvQ**

Plant Cuttings

Editors' note: News excerpts are clipped from a diversity of sources. To read the articles in full follow the links attached to each clipping. The views expressed in these articles are those of their authors and do not necessarily represent the opinion of the ANPC.

Wetland Revival Trust hopes to raise funds to buy Wirra-Lo conservation property in Victoria – ABC, 28 July 2022

A unique property in northern Victoria that is home to 30 threatened species, including the Australasian bittern and growling grass frog, is up for sale and a not-for-profit ecological trust is hoping it can raise the funds to continue the vision of its current owners. Ken and Jill Hooper purchased Wirra-Lo in the 1980s and the summer pastures that were grown there complemented their dairy business in nearby Cohuna.
https://www.abc.net.au/news/2022-07-28/wetland-revival-trust-fundraising-to-buy-conservation-property/101272802

Eucalypts are icons of the Australian landscape, but their family tree is shrouded in mystery – ABC Science, 31 July 2022

Dean Nicolle struggles to name his favourite species of eucalyptus. "If I had to put a name down, my favourite species would change every day," he says. "It depends upon whether I am in the field, or if I'm out in the wild, or what's in flower or the colours of the bark at the time." But there is one species, he admits, that has a particular place in his heart at any time of the year because it is so rare.
https://www.abc.net.au/news/science/2022-07-31/eucalyptus-native-trees-evolution-dominate-australia-landscape/101229092?utm_campaign=abc_news_web&utm_content=link&utm_medium=content_shared&utm_source=abc_news_web

The mystery surrounding Australia's ancient wild and endangered macadamia trees – ABC Rural, 31 July 2022

Ian McConachie is eager to find the answer to an ancient mystery — just how many hundreds of years do Australia's wild macadamias live? After decades of visiting a precious remnant of the threatened species' habitat in Queensland's Amamoor State Forest, the founder of the Macadamia Conservation Trust has already discovered that looks can be deceiving.
https://www.abc.net.au/news/rural/2022-07-31/wild-macadamias-threatened-species-genetics-amamoor/101276254

15 years of experiments have overturned a major assumption about how thirsty plants actually are – The Conversation, 9 August 2022

Have you ever wondered just how much water plants need to grow, or indeed why they need it? Plants lose a lot of water when they take in carbon dioxide from the atmosphere, so they need up to 300 grams of water to make each gram of dry plant matter.
https://theconversation.com/15-years-of-experiments-have-overturned-a-major-assumption-about-how-thirsty-plants-actually-are-188072

Southern conifers: meet this vast group of ancient trees with mysteries still unsolved – The Conversation, 10 August 2022

When you think of "conifers", tall, conical shaped trees often found in public parks or front yards may spring to mind. But these impressive trees are far more fascinating than you may have realised, as they represent just one piece of an unsolved botanical puzzle.
https://theconversation.com/southern-conifers-meet-this-vast-group-of-ancient-trees-with-mysteries-still-unsolved-182600

Botanist fights to save cycads, the 'dinosaur' plants threatened by land clearing and zealous collectors – ABC Radio Sydney, 19 August 2022

James Clugston was on the hunt for a type of tarantula called a "baboon spider" in South Africa when something else grabbed his attention. "This one plant stood out to me … it's blue, but it's super, super spiky. I'm like, 'What is that? That is amazing'," he said. The odd-looking prickly plant — Encephalartos horridus — is a member of the cycad family and sparked an interest in the species that would turn into Dr Clugston's life's work.
https://www.abc.net.au/news/2022-08-19/cycad-dinosaur-plants-conservation-botanic-garden-sydney/101347332

After planting thousands of wattles, farm goes from 'bare paddocks' to teeming with wildlife – ABC Rural, 23 August 2022

When Mikla Lewis took over a cropping farm near Grenfell in the New South Wales central West in 2002, almost all of the land's native plants had been cleared. Two decades later she has planted thousands of wattles,

turning her property into an oasis for almost 200 different native animals.
https://www.abc.net.au/news/rural/2022-08-23/wattles-planting-nsw-farm-revitalise-bare-paddocks-wildlife/101356662

Crocodile, jellyfish threat as volunteers race to restore tropical harbour's forgotten seagrass meadows – ABC Far North, 27 August 2022

A team of scientists and volunteers is racing to give nature a helping hand in Queensland's tropics — if nature's deadliest creatures don't get to them first. When Cyclone Yasi tore through the picturesque Mourilyan Harbour south of Cairns a decade ago, the category five monster system destroyed seagrass meadows that provided vital food and shelter for marine life.
https://www.abc.net.au/news/2022-08-27/seagrass-meadows-reforest-mourilyan-harbour/101360538

How the Ice Ages spurred the evolution of New Zealand's weird and wiry native plants – The Conversation, 29 August 2022

Recent genetic research has shed new light on the long-running debate about the evolutionary origins of some of New Zealand's quirkiest plants.
https://theconversation.com/how-the-ice-ages-spurred-the-evolution-of-new-zealands-weird-and-wiry-native-plants-188140

Effectiveness of the Biodiversity Offsets Scheme - Audit Office of NSW, 30 August 2022

The Audit Office of New South Wales released their report yesterday which examined whether the Department of Planning and Environment (DPE) and the Biodiversity Conservation Trust (BCT) have effectively designed and implemented the Biodiversity Offsets Scheme to compensate for the loss of biodiversity due to development. Their findings are available here.
https://www.audit.nsw.gov.au/our-work/reports/effectiveness-of-the-biodiversity-offsets-scheme

Another wet Sydney summer isn't just bleak — it could wipe out an entire species – The Sydney Morning herald, 31 August 2022

The Royal Botanic Garden is racing to save entire plant species at risk of extinction from diseases that thrive in the rain, as Sydney faces the bleak prospect of another long, wet summer. Chief botanist with the botanic gardens Dr Brett Summerall said there are 16 species – including the native guava and scrub turpentine on the North Coast – that are at serious risk of being wiped out forever by myrtle rust, a disease that thrives in warm weather and wet conditions.
https://www.smh.com.au/environment/weather/plant-species-under-threat-as-sydney-braces-for-wettest-year-on-record-20220829-p5bdol.html

Carnivorous Albany pitcher plant threatened by poachers, but still baffles scientists – ABC Great Southern, 1 July 2022

It has curled teeth and an appetite for devouring creatures. The Albany pitcher plant eats its prey of insects and flies by snaring them with trickery and then dissolves them with enzymes. Its incredible survival adaptation and appearance has made it one of the most sought-after carnivorous plants by collectors across the world.
https://www.abc.net.au/news/2022-07-01/carnivorous-pitcher-plant-poachers-scientists/101197086

AUDIO: Chelsea McDonald and her daughter Jasmine get ready to plant – ABC, 6 July 2022

When you think of the term 'bush doof', you probably think of psychadelics, techno music and prolonged hangovers. But not all bush doofs were created equal. Hundreds of volunteers gathered at a rural property in Wyalkatchem over the weekend with a different goal in mind, to give back to nature by planting 100,000 trees.
https://www.abc.net.au/news/2022-07-06/tree-planting-festival-wa-wheatbelt/101211684

Activate Tree Planting festival in WA Wheatbelt helps farmland rehabilitation – ABC Midwest & Wheatbelt, 6 July 2022

Being a treehugger can be difficult in Western Australia's Wheatbelt — after decades of intensive deforestation, there just aren't many left to hold. But this may not be the case for future generations, thanks to the hundreds of hands that gathered at the weekend to revegetate an area of the salt-stricken land.
https://www.abc.net.au/news/2022-07-06/tree-planting-festival-wa-wheatbelt/101211684

Prickly pear was conquered 90 years ago. Here's how it was done – ABC Southern Qld, 10 July 2022

Farming has been in the Geldard family for four generations, but one plant almost brought them to their knees early on. Prickly pear is considered one of the greatest biological invasions of modern times, infesting millions of hectares of rural land in Australia a century ago and rendering it virtually useless and worthless.
https://www.abc.net.au/news/2022-07-10/90-years-since-prickly-pear-conquered/101222202

Mistletoe die-off bad news for woodland birds – Australian National University, 13 July 2022

Mistletoe plants suffered widespread die-off during the recent 2019-20 drought, and it spells bad news for Australia's woodland birds, new research from The Australian National University (ANU) shows.
https://www.anu.edu.au/news/all-news/mistletoe-die-off-bad-news-for-woodland-birds

Botanists are disappearing – just when the world needs them most – The Conversation, 14 July 2022

Can you recall any of the plants you saw today? Probably not. As a species, we are not programmed to recognise and register everything we see within our field of vision. This would be an overwhelming amount of information for our brains to process. You can however, with a little time and practise, be trained to read the plants around you.
https://theconversation.com/botanists-are-disappearing-just-when-the-world-needs-them-most-186849

Media release: New mapping method unearths bigger mangrove area in north west – The University of Western Australia, 15 July 2022

A new mapping method has increased the size of the known mangrove area in north-western Australia by more than 30 per cent, a finding that will help protect the vulnerable ecosystem. Dr Sharyn Hickey, from The University of Western Australia's School of Agriculture and Environment and the Oceans Institute, and Dr Ben Radford, from the Australian Institute of Marine Science, co- authored the paper, *Turning the Tide on Mapping Marginal Mangroves with Multi-Dimensional Space–Time Remote Sensing* published in *MDPI*.
https://www.uwa.edu.au/news/Article/2022/July/New-mapping-method-unearths-bigger-mangrove-area-in-north-west

Millions of pine trees to be planted in Tumut and Tumbarumba as forestry recovers from bushfires – ABC Rural, 20 July 2022

The Tumut and Tumbarumba region in southern New South Wales is home to Australia's largest timber plantation. Right now, its planting season and the program is bigger than ever before. More than 100 crew members are out in cold, wet and sometimes snowy conditions, to plant more than 6.5 million trees by hand between May and late August.
https://www.abc.net.au/news/rural/2022-07-20/softwood-forestry-industry-timber-demand-bushfire-recovery/101247384

Eucalypt found only in Sydney suburbs confirmed as new species – ABC Radio Sydney, 21 July 2022

An incredibly rare eucalypt found in some of the most densely developed areas of Sydney has been confirmed as a new species. The yet-to-be formally named species is a shrubby type of eucalypt with cup-shaped fruit and is found in the Hills District in Sydney's north-west.
https://www.abc.net.au/news/2022-07-21/new-eucalypt-species-sydney-botanic-gardens/101255680

The trees that make you sneeze - Australian National University, 21 July 2022

Did you know Canberra is the allergy capital of Australia? No, we aren't 'pollen' your leg. Gouri Banerji finds out what trees and plants can cause hay fever havoc. Sniffles, sneezes and scratchy eyes ... hay fever season is coming! So it's a good time to clear the air and learn more about the trees that make you sneeze.
https://www.anu.edu.au/news/all-news/the-trees-that-make-you-sneeze

I spent a year squeezing leaves to measure their water content. Here's what I learned – The Conversation, 26 July 2022

How do you tell if your plants need water? Recently, I asked this question of a group of about 40 biologists at the Australian National University. Most of them said they would stick their fingers into the soil. If you want to be more scientific about it, most horticulturalists would argue it is best to weigh the pot to determine how much water it contains.
https://theconversation.com/i-spent-a-year-squeezing-leaves-to-measure-their-water-content-heres-what-i-learned-187460

Media Release: Native New Zealand tree puts the sting on pain – The University of Queensland, 27 July 2022

Researchers at The University of Queensland have found that a native New Zealand stinging tree produces toxins that could hold clues for future pain medication.

In a quest to find new molecules that affect pain pathways, Dr Thomas Durek, Dr Sam Robinson and a team from UQ's Institute for Molecular Bioscience (IMB) studied toxins from the tree nettle known as ongaonga, one of New Zealand's most poisonous plants that can cause painful stings that last for days, and in severe cases can even be fatal.
https://www.uq.edu.au/news/article/2022/07/native-new-zealand-tree-puts-sting-pain

Media release: Gulf mangrove dieback discovery – James Cook University, 28 July 2022

The latest research reveals that the devastating mass death of tidal mangrove forests was a result of an unusually low sea-level due to large-scale swings in El Nino – Southern Oscillation events. Lead author Dr Norm Duke from JCU's TropWATER Research Centre said the mangroves had not recovered seven years on, making the mangrove dieback event an ongoing coastal catastrophe.
https://www.jcu.edu.au/news/releases/2022/july/gulf-mangrove-dieback-discovery

World's largest plant discovered right under our noses in Western Australia – ABC Science, 1 June 2022

You'd think that the world's largest plant would stand out like a sore thumb. But researchers have today revealed there's a plant about 4,500 years old and measuring 180 kilometres across living right under our noses in Western Australia.
https://www.abc.net.au/news/science/2022-06-01/worlds-largest-plant-seagrass-meadow-shark-bay-giant-clone/101112726

Meet the world's largest plant: a single seagrass clone stretching 180 km in Western Australia's Shark Bay – The Conversation, 1 June 2022

Next time you go diving or snorkelling, have a close look at those wondrously long, bright green ribbons, waving with the ebb and flow of water. They are seagrasses – marine plants which produce flowers, fruit, and seedlings annually, like their land-based relatives.
https://theconversation.com/meet-the-worlds-largest-plant-a-single-seagrass-clone-stretching-180-km-in-western-australias-shark-bay-184056

Media Release: Boost to local Endangered plant Harrow Wattle, Threatened Species Conservancy, 6 June 2022

The Endangered Harrow Wattle (*Acacia acanthoclada*) is threatened by overgrazing from feral goats. Mothers Ancestral Guardians Indigenous Corporation and the Threatened Species Conservancy have set up enclosures to exclude grazers at Rick Farley Soil Conservation Reserve near Pooncarrie. Seeds were planted in the enclosures in autumn and Harrow Wattle was also found regenerating within the fenced site.
https://www.facebook.com/ThreatenedSpeciesConservancy/

Media release: Post-fire survey success along Shoalhaven River – Threatened Species Conservancy, 15 June 2022

Recent surveys along the Shoalhaven River have found Bombay Bossiaea (*Bossiaea bombayensis*) survived the 2019 bushfires. This vulnerable species is only known from one location. The surveys also found seedlings and hundreds of Bombay Bossiaea plants about to flower and set seed. **https://www.facebook.com/ThreatenedSpeciesConservancy/**

VIDEO: Air Seed: Planting Trees from the sky – Landline, 19 June 2022

Inventors of an Australian innovation hope to plant up to 40,000 trees a day in remote and difficult to access areas.
https://www.abc.net.au/news/rural/programs/landline/2022-06-19/air-seed:-planting-trees-from-the-sky/13944748

Growing salt-tolerant plants will fix land damaged due to European farming methods, WA farmer says – ABC 22 June 2022

Tucked away in a tree plantation south-east of Perth, a saltwater greenhouse that may be one of a kind is growing salty plants for innovative restaurants. "I don't know anyone in Australia who's done it," Katanning farmer and owner of Moojepin Foods, David Thompson said of the saltwater hydroponic system.
https://www.abc.net.au/news/rural/2022-06-22/saltwater-greenhouse-grows-restaurant-salt-bush-salad/101170718

Digitising the Australian National Herbarium may help us better understand how plants respond to climate change, researchers say – ABC, 24 June 2022

A new high-resolution camera at the CSIRO is set to photograph one million plant specimens in nine months, as researchers look into how the natural world is changing. The plant objects, many collected as far back as a century ago, are being stored at the Australian National Herbarium in Canberra, but according to CSIRO group leader for digitisation Pete Thrall, it would take about eight years to digitise all of the specimens using a regular camera.
https://www.abc.net.au/news/2022-06-24/digitising-plants-csiro-australian-national-herbarium/101182468

Aboriginal farmers in Western Australia sow the seed for carbon credits and land restoration – ABC, 29 June 2022

Between mining companies' carbon offsets and farmers' land restoration projects, the market for native tree seedlings is booming and seed suppliers are having difficulty keeping up.
https://www.abc.net.au/news/2022-06-29/aboriginal-farming-wa-collective-regrowing-bush-native-tree-seed/101190780

Aboriginal farmers sow the seed for regeneration – ABC, 29 June 2022

A group of Aboriginal farmers plans to triple the size of a native tree nursery to meet booming demand for carbon farming and land regeneration.
https://www.abc.net.au/radio/programs/am/aboriginal-farmers-sow-the-seed-for-regeneration/13950882

Events and opportunities

New podcast – ESA launches Ecology Matters

The Ecological Society of Australia have begun a new podcast called Ecology Matters with one episode being released each week. The first series contains 12 episodes where you will hear from ecologists around Australia. Find it wherever you get your podcasts or on their website.
https://www.ecolsoc.org.au/publications/audio/ecology-matters/

Landcare Conference recordings available

The video recordings, presentations and posters from the 2022 National Landcare Conference held in August 2022 are now available on the Landcarer website.
https://www.landcarer.com.au/blogs/melanie-hartley/2022/08/18/landcareconf22-education-resources

Save the date –2023

The International Conservation Translocation Conference is being held in Fremantle, Western Australia next year from 13-15 November 2023. No further information available but save the date in your calendar!
https://conservationtranslocations.com/

ESA Joint Conference

The conference of the Ecological Society of Australia and the Society for Conservation Biology Oceania will be held in Wollongong, NSW from 28 November to 2 December 2022. ESA-SCBO 2022 will be an in-person conference but a limited number of online options will be offered, including live-streamed plenaries, some live-streamed symposia and some of the presentations being made available online after the conference.
https://www.esascbo2022.org.au/

Forum recordings available

Video recordings of the presentations and presenter slides for the NSW Roadside Environment Committee Forum are now available online
https://www.molinostewart.com.au/2022-roadside-environment-committee-forum/

Kelp restoration guidebook – free download

Kelp forests around the world are experiencing significant declines due to a variety of factors, driving the need for more active kelp restoration efforts. The science and practice of kelp forest restoration is still in its infancy and there remains a wealth of knowledge to be learned and shared from our collective failures and successes. This guidebook is intended to serve as a starting point for practitioners, researchers, managers, and custodians to learn about the steps of restoration and access an active community of practice—all to improve the likelihood of success for future kelp restoration projects.
https://www.scienceforconservation.org/products/kelp-restoration-guidebook

Ten simple rules towards healthier research labs – reshare from 2019

The negative effects of extremely competitive academic and research environments on the performance and health of researchers are well known and common worldwide. The prevalence of these effects, particularly among early career researchers, calls for a more humane and people-centered way of working within research labs. Although there is growing concern about the urgent need for a better life–work balance when doing science, there are not many examples about how this could be achieved in practice. In this article, I introduce 10 simple rules to make the working environment of research labs more nurturing, collaborative, and people-centered. These rules are directed towards existing and future principal investigators (PIs) but will be of interest to anyone working in a research lab and/or dealing with how to improve working conditions for scientists.
https://journals.plos.org/ploscompbiol/article?id=10.1371/journal.pcbi.1006914

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Department of Biodiversity, Conservation and Attractions, WA

Department of Planning, Industry and Environment, Saving Our Species, NSW

Environment, Planning and Sustainable Development Directorate, ACT

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Photo credit: Michael Lawrence-Taylor

Plants Going Places

Capacity building in the translocation of Victoria's threatened native plants

Our Plants Going Places project aimed to build capacity for plant translocations in Victoria by increasing awareness of threatened plants, giving a voice to people who work in this field and tackling "plant blindness". To achieve this we produced a series of videos and podcasts on plant translocation projects and a two-day online symposium.

Videos and Podcasts

Our producer Chantelle Doyle and videographer Michael Lawrence-Taylor produced videos and podcasts on the Spiny Rice Flower (*Pimelea spinescens* subsp. *spinescens*) in the Brimbank City Council area, Murnong yam daisy (*Microseris scapigera*) at Merri Creek in Melbourne and orchids in Victoria. To watch or listen to these stories head to the project webpage **https://www.anpc.asn.au/plants-going-places/**

Symposium

We held our Symposium over two days in July 2022 and have an incredible range of presentations from experts and practitioners in plant translocations. To watch the recordings from the Symposium please head to our YouTube channel

https://www.youtube.com/c/AnpcAsnAu

For more great videos and podcasts by Chantelle and Michael visit the Plant Heroes website

Plant Heroes

https://www.plant-heroes.com/

Australian Network for Plant Conservation Inc

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